AN ANALYSIS OF THE PERFORMANCE OF THE HIGH YIELDING VARIETIES PROGRAMME FOR PADDY IN COIMBATORE DISTRICT, TAMIL NADU, INDIA

by

Kaliappa Pillai KALIRAJAN

A dissertation submitted for the degree of

Doctor of Philosophy

in the Australian National University

September, 1979

DECLARATION

Except where otherwise acknowledged in foot notes, this dissertation is the original research of the author.

M. Maliyan.

ABSTRACT

This dissertation demonstrates the dynamic nature of the new rice technology, particularly in relation to the changing demands placed upon agricultural research. It brings out the range of actual field performances of the location specific high yielding varieties recently evolved through decentralised research, in comparison with those of the exotic or imported high yielding varieties in an area without major constraints on performance. It thus highlights the importance of location specific research in the development of new technology in India. Without serious external constraints including risk, this study shows that these new paddy varieties have better field performances measured in terms of productivity, economic efficiency, net profits, and assesses the distribution of benefits amongst participants. The study also suggests directions for further research to increase productivity further and to improve monetary gains and their distribution.

ACKNOWLEDGEMENTS

It is indeed very difficult for me to express in words my sincere gratitude to my supervisors Dr R.T. Shand and Dr R.M. Sundrum. Dr Shand introduced me to agricultural economics, and particularly to the 'Green Revolution', and gave his valuable time and knowledge unstintingly in helping this study move faster and in the right direction. I am sure it must have been painful for him when reading my earlier drafts; but always with a smile he made numerous valuable suggestions towards the improvement of this study. Dr Sundrum, despite being very busy, listened to me patiently and made valuable comments and helpful suggestions on my earlier drafts. To these two knowledgeable and kind-hearted men, I am indebted for the rest of my life.

I am grateful to Mr G.S. Corra, who provided me with the basic programme for maximum likelihood estimation and to Ms E. Davis for her valuable assistance in running various programmes on the DEC10 and UNIVAC computers.

I am also grateful to Mr C. Manimanthiri, Deputy Director of Agriculture, Coimbatore District, Professor A. Subramanian and Professor V. Rajagopalan of Tamil Nadu Agricultural University whose enthusiasm for this study was very valuable during my field work in Coimbatore district.

Acknowledgement is also due to Professor H.W. Arndt, Professor John D.K. SunderSingh, Dr C. Barlow, Mr E.K. Fisk, Dr D.M. Etherington, Dr R.P. Byron, Mr D.B. Evans and Mr S. Divakar for their help and suggestions at various stages of the study.

I am thankful to all the officials in the Office of the District Agricultural Officer, Gobichettipalayam, Gobichettipalayam Panchayat Union, Co-operative Society for their help during my field work. Mr M. Deivasikamani, Plant Protection Officer, Gobichettipalayam needs a special thanks for his assistance in appointing my investigators. For the data of this study I owe a great deal to my investigators Mr R. Jagannathan and Mr K. Chandrasekaran who assisted me in data collection sincerely and efficiently and to all my sample participants in Seyyampalayam village for their co-operation.

The help by the computing staff, especially Y. Pittlekow, and members of the secretarial staff of the Department of Economics, especially Mrs E. Harriss, and Ms S. Moro, is appreciated with many thanks.

I am thankful to the Madurai University, for granting me study leave and to the Australian National University for awarding me the Scholarship.

I also thank sincerely Mrs D. Boucher for typing this dissertation from my hand written copy with her superb skill.

My acknowledgement will not be a true one, if I did not acknowledge the moral courage and support rendered to me by my wife Dhamayanthi and my two sons Kaleeswaran and Sankareswaran throughout the course of this study.

CONTENTS

MAP, TABLES AND FIGURES

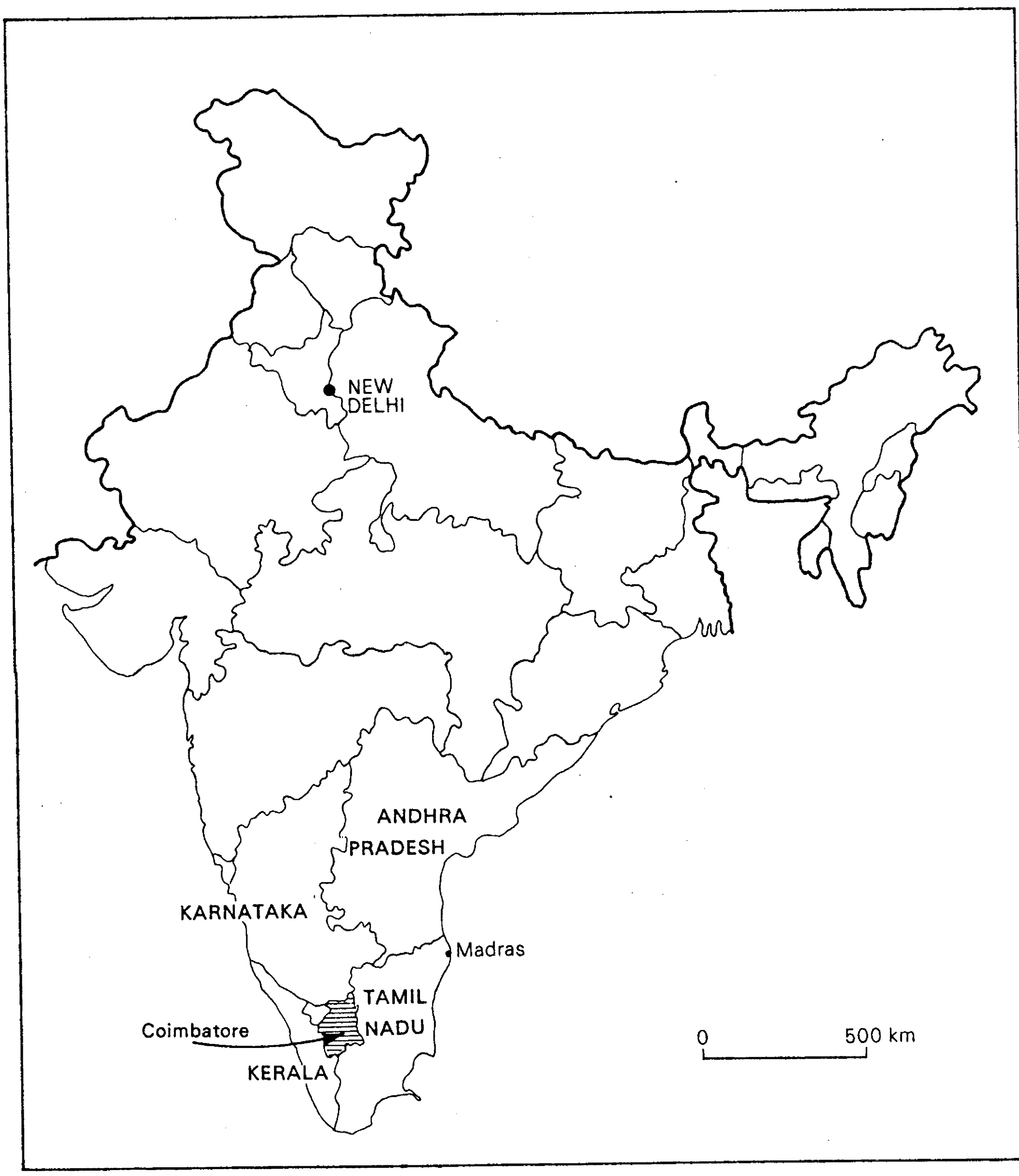
Page

MAP

TABLES

FIGURES

****



INDIA: Coimbatore District

CHAPTER 1

INTRODUCTION

In most developing countries, agriculture is the dominant sector, measured in terms of employment of resources and of income generation. Above all, it is a source of livelihood and sustenance for the majority of people within it, and its growth provides the greatest hope of higher standards for this majority. It also provides a surplus of food, raw materials,[1] capital and labour to other sectors, hence the development of agriculture plays a major role in total economic development,[2] and formulation of agricultural development strategies is a crucial factor in this. Choice of strategy depends on the characteristics of the sector, and the latter conditions the direction of the growth process.[3]

At any point of time, an agriculture production system can be characterised by four basic resource-technology situations: unlimited land - static technology; limited land - static technology; unlimited land - dynamic technology and limited land - dynamic technology.[4] In the first situation, where both land use and labour supplies are increasing, but production techniques are static, the growth of agricultural output depends on the quality of land under cultivation. In the second situation, only

---

1 Kuznets, S. (1969) Economic Growth and Structure, Oxford and IBH Publishing Co., New Delhi, (p.239).

2 Hayami, Y. and V.W. Ruttan (1971) Agricultural Development: An International Perspective, The John Hopkins Press, London, (p.286).

3 Mellor, J.W. (1967) 'Towards a Theory of Agricultural Development', in H.M. Southworth and B.F. Johnston (eds.) Agricultural Development and Economic Growth, Cornell University Press, Ithaca, New York, (p.37).

4 Shand, R.T. (1969) 'Perspectives on Asia' in R.T. Shand (ed.) Agricultural Development in Asia, Australian National University Press, Canberra, (pp.314-22).

labour supply is increasing and other factors of production either remain constant or are declining. Under these circumstances, government development policies should commence to play an important role in raising productivity in agriculture. The third situation, where all the factors of production are increasing needs no explanation. The last situation is a limiting case of the third, where the scarce factor is land area under cultivation. In this case, growth of output depends on intensive and scientific applications of other inputs. This is the situation that involves the great majority of farmers in developing countries, and is the one that concerns us in this study.

The existence of various combinations of resource-technology situations in different countries and even in different parts of a country means there are multiple paths of technological development. Mainly there are two constraints imposed on agricultural development: (i) an inelastic supply of land; and (ii) an inelastic supply of labour. The former problem may be overcome by improving the existing biological technology, whereas the latter may be offset by developing mechanical technology. The ability of a country to achieve rapid growth in agricultural output and productivity seems to hinge on its ability to make an efficient choice among the alternative paths.[5]

The next section briefly describes important approaches for increasing agricultural productivity and output in developing countries which are relevant to the main focus of this study - the performance of the new research-based agricultural technology. Following this, a brief review is given of Indian agricultural development programmes since Independence,

---

5 Hayami, Y. and V.W. Ruttan (1971) (pp.52-5).

showing India's increasing dependence on the strategy of increasing land productivity. A third section spells out the main objectives and hypothesis of the present study, and a final section provides a summary of the structure of this study by chapters.

Choice of Strategies for Agricultural Development

Schultz advocates 'the high pay-off input' model for most of the developing countries to increase the food production and other farm products. Basically, the model emphasises the following three points: (i) an efficient system of prices; (ii) a supply of high pay-off agricultural inputs; and (iii) the development of sources of these high pay-off agricultural inputs.[6] An efficient pricing system for agricultural inputs and outputs and consumer goods sets the stage for farmers to make the best possible use of the resources available to them. Once these have been exhausted, further progress in agriculture depends on the development and application of new profitable inputs. The evolution of these profitable inputs is determined by the capacity and strength of agricultural research.[7] However, Schultz's model did not explain the ways of achieving and distributing the high pay-off inputs in any economy.

Hayami and Ruttan criticised Schultz's model on the grounds that it did not explain the process of development and spread of new agricultural techniques and the mechanism of resource allocation, including agricultural research. They proposed an 'induced development model' based on the theory of induced innovations, that incorporates Schultz's model but additionally

---

6 Schultz, T.W. (1968) Economic Growth and Agriculture, McGraw Hill Book Company, New York, (p.9).

7 Schultz, T.W. (1964) Transforming Traditional Agriculture, Yale Universit Press, New Haven.

discusses the mechanism which brings about the changes envisaged by Schultz. Briefly, the induced development model explains 'the process by which the public sector investment in agricultural research, in the adaptation and diffusion of agricultural technology and in the institutional infrastructure that is supportive of agricultural development, is directed towards releasing the constraints on agricultural production imposed by the factors characterised by a relatively inelastic supply'.[8]

Japan's agricultural development is a good example of this type of development process. The conditions of Japanese agriculture during the initial stages of industrialisation, were a very unfavourable man-land ratio and a relatively low level of labour productivity in agriculture, implying a low level of general economic performance, i.e., a fairly typical Asian type of agriculture.[9] But rapid agricultural development was achieved by the combination of two main kinds of improvement: (i) land improvement, including better irrigation and drainage facilities; and (ii) evolution of superior seeds, better methods of crop cultivation and increased input of manures and fertilisers.[10] A combination of improved biological technology favourable market conditions for agricultural commodities and appropriate government programmes and policies helped to carry out the improvements constantly and rapidly.[11] The important lesson to be learnt from the Japanese experience is that modern agriculture progressively modified

---

8 Hayami, Y. and V.W. Ruttan (1971) (p.54).

9 Ohkawa, K. and H. Rosovsky (1960) 'The Role of Agriculture in Modern Japanese Economic Development', Economic Development and Cultural Change, Vol. IX, No. 2 (pp.43-68).

10 Ibid., (p.50).

11 Crawcour, E.S. (1969) 'Japan, 1868-1920', in R.T. Shand (ed.), Agricultural Development in Asia, ANU Press, Canberra (pp.1-24).

existing traditional farming systems rather than replaced it. Japan demonstrated that even with small-scale and labour-intensive agriculture, widespread adoption of yield-increasing innovations would enable the contribution of agriculture to economic growth to be increased substantially.[12] Thus, Japan's achievements were remarkable and impressive and still offer the best model for Asian economic development.[13]

There are two major approaches to raising agricultural output: horizontal and vertical. The horizontal approach involves bringing more land under cultivation, stepping up supplies of specific inputs like water and fertiliser, and providing farmers with economic incentives in the form of favourable factor-product price ratios. In this approach, the accent is not directly on technological improvement. The vertical approach, on the other hand, involves technological transfer with an appropriate institutional framework of production methods. In accord with Schultz's theory, it envisages growth of output from increases in output per unit area rather than expansion of area planted. As Hayami and Ruttan argue, technological transfer is achieved through integrated development of the public and private sector engaged in building up agricultural infrastructure, including research and extension.

For countries faced with growing population pressures on available land and low crop yields, the choice of a strategy for achieving increased output is mainly confined to a 'restricted vertical or land-saving approach'. A restricted approach implies that technical transfer should be first attempted in some selected areas which have a known and ready potential for

---

12 Johnston, B.F. (1966) 'Agriculture and Economic Development: the Relevance of Japanese Experience', Food Research Institute Studies, Vol. VI, No.3 (pp.251-312).

13 Nicholls, W.H. (1964) 'The Place of Agriculture in Economic Development', in C. Eicher and L. Witt (eds.), Agriculture in Economic Development, McGraw-Hill, New York.

development. This approach not only helps a country to increase its foodgrain production quickly, but also, has a demonstration effect on other less developed areas and encourages them to participate in the process of technological transfer of the economy.[14] If the objective of maximisation of the overall rate of agricultural growth is to be attained, it seems desirable to concentrate investment in the 'assured' areas at any rate in the short run. However, the success of the programme that brings about technological transfer in agriculture depends on a number of complementary programmes, which transform the 'transfer' into a sustained growth of output.

Motivation is a crucial factor determining whether or not individual farmers will attempt to maximise net income. Motivation in turn is influenced by institutional and market factors, of which resource ownership and pricing are important. Minhas and Srinivasan have pointed out that owner cultivators are more motivated to use fertilisers than tenant cultivators, for profit from fertiliser use is enjoyed solely by owner cultivators, while tenant cultivators have to share profits with the landlord.[15] Government policies and programmes regarding tenancy, share cropping and allied aspects of land reforms have an important influence on the pace of modernisation of agriculture through technological transformation.

Similarly, pricing policies affect farmers motivation. The farmer naturally enough wants cereal prices to be maintained or even increased, and input prices of fertilisers and pesticides to decline. On the other

---

14 'Again the institutional inflexibilities implicit in a developing economy dictate that a selective rather than a universal approach be adopted'. [Mujumdar, N.A. (1970), 'Intra-sectoral Dualism and Agricultural Growth', Economic and Political Weekly, Vol. V, No. 26, (pp.A2-A5)].

15 Minhas, B.S. and T.N. Srinivasan (1967) 'New Agricultural Production Strategy Analysed', Yojana, Vol.X, No.1 (pp.20-4).

hand governments of most developing countries are committed to holding foodgrain prices down to serve consumer interests. Resolving these two conflicting interests is a difficult and continuing process. With a vertical approach, however, productivity gains are made with rising yields and costs of production reduced. If prices also keep on rising, the approach is bound to have an adverse effect on other aspects of the economy such as costs, inflation etc. Thus, farmers should be made to understand that their emphasis on price as the basis of motivation is wrong and the emphasis should be on the income maximisation rather than price maximisation.[16] However, as Dantwala[17] argues, the impact of land reforms and developmental programmes aiming at institutional changes would be rather limited on traditional agriculture. In dry regions for example, measures to increase productivity will yield more contribution to economic growth than the imposition of ceilings on holdings. In short, in developing countries with growing populations, the hope for increased production lies with the means of increasing the productivity of land.[18] It is argued in the following section, that in India, only the 'new agricultural strategy' has significantly raised productivity over the last decade.

Indian Agricultural Development

Agriculture, with nearly three-fourths of the population engaged in its activities and contributing a little less than half of national

16 Rao, V.K.R.V. (1966) Agricultural Development in the Fourth Plan, Planning Commission, Government of India.

17 Dantwala, M.L. (1973) 'From Stagnation to Growth: Relative Roles of Technology, Economic Policy and Agrarian Institutions', in R.T. Shand (ed.) Technical Change in Asian Agriculture, Australian National University Press, Canberra.

18 Hayami, Y. et al. (1976) 'Agricultural Growth Against Land Resource Constraint: The Philippine Experience', Australian Journal of Agricultural Economics, Vol.20, No.3, (pp.144-59).

income, far exceeds other sectors of the Indian economy in importance. Approximately three-quarters of total sown area is sown to food crops, mainly cereals and pulses, with production of cereals predominant. On the eve of the First Five Year Plan, India had a serious food shortage that led to primary emphasis being placed on agricultural development in the First Plan.[19] During this period, the rate of growth of food output was over 7 per cent. Production of foodgrains increased from 41.7 million tonnes in 1945-50 to 65 million tonnes in 1955-6. It was in the course of the Second Plan that the first real doubts about the nation's capacity to raise food production were realised. During this Plan period, food output grew by less than three per cent per year, and by 1960-1, the end of the Plan period, food production was 79 million tonnes, against a target of 81.8 million tonnes. At that time, demand for foodgrain was rising at a rate of 3.8 per cent per year, mainly as a result of a population growth rate of 2.5 per cent per annum, and in the 1960s the gap between domestic supply and demand tended to widen. The import of total cereals showed a rising trend from the late 1950s (Table 1.1). The two severe drought years of 1966 and 1967 greatly widened the gap. Throughout the Second and Third Plan periods there was a pressure of demand from a rapidly growing population. This was magnified by a growing urban workforce resulting from the planned process of industrialisation and from unplanned urban drift of rural population. There were increased industrial investment outlays in these periods and also unfavourable weather conditions and hoarding of stocks by traders expecting rises in prices. On the world market, demand was

---

19 Crawford, J.G. (1969) 'India', in R.T. Shand (ed.) Agricultural Development in Asia, The Australian National University Press, Canberra.

TABLE 1.1

INDIA: IMPORTS OF CEREALS 1950 TO 1975

Year	Rice	Wheat	Other Cereals	Total Cereals	Imports of Cereals as Percentage of Domestic Production	Value of Imports
	(- - - - million tons			- - - -)	(%)	(million Rs.)
1950	0.36	1.43	0.37	2.16	4.6	806.0
1951	0.76	3.06	0.98	4.80	11.3	2,167.9
1952	0.74	2.55	0.64	3.93	9.0	2,090.7
1953	0.18	1.71	0.15	2.04	4.1	859.5
1954	0.63	0.20	0.01	0.84	1.4	485.3
1955	0.17	0.34	-	0.51	1.0	331.1
1956	0.29	1.10	-	1.39	2.5	563.4
1957	0.75	2.88	-	3.63	6.2	1,623.9
1958	0.40	2.71	0.11	3.22	5.9	1,205.1
1959	0.30	3.55	0.02	3.87	6.0	1,414.1
1960	0.70	4.39	0.05	5.14	7.9	1,928.4
1961	0.38	3.09	0.04	3.50	5.1	1,295.6
1962	0.39	3.25	-	3.64	5.1	1,410.9
1963	0.48	4.07	0.01	4.56	6.6	1,836.0
1964	0.65	5.62	-	6.27	8.9	1,662.5
1965	0.78	6.58	0.10	7.46	9.7	2,903.2
1966	0.79	7.78	1.79	10.36	16.6	2,231.3
1967	0.45	6.35	1.87	8.67	13.2	5,321.6
1968	0.45	4.77	0.47	5.69	6.9	3,612.0
1969	0.49	3.09	0.29	3.87	4.6	2,530.1
1970	0.21	3.42	-	3.63	4.1	2,075.5
1971	0.24	1.81	-	2.05	2.1	1,234.6
1972	0.12	0.33	-	0.45	1.9	230.3
1973	-	3.22	0.39	3.62	16.2	...
1974	n.a.	n.a.	n.a.	4.87	4.7	...
1975	n.a.	n.a.	n.a.	7.41	7.3	...

Note: n.a. - not available.

Sources: (1) Directorate of Economics and Statistics (1962, 1972) Bulletin on Food Statistics, Ministry of Agriculture and Irrigation, Government of India Press, New Delhi.

(2) IBRD (1974) Economic Situation and Prospects of India, Vol.III, Statistical Appendix.

increasing and rising prices made it more difficult for India to obtain required foodgrain imports. The domestic shortfall in food supplies became the main obstacle in the way of planned development in India, while the high cost of commercial imports reduced India's other options. Self-reliance in foodgrain accordingly came to be given top priority in agricultural development planning for the country.

During the First and to a significant extent, Second Plan periods, extensions of the area under cultivation played an important role in bringing about the increase in agricultural production. The country thus relied substantially on the 'horizontal approach' of agricultural development, which was propagated through various programmes.

National Extension Service (NES) and Community Development Programme (CDP). The 'vertical approach' first became manifest in the form of the National Extension Service and Community Development Programme, inaugurated in October 1952, in which 15 pilot projects were launched in different parts of the country. The objective with these two intensive and comprehensive programmes was to improve all aspects of rural life, namely, agriculture, rural industries, education, health and housing, and to utilise the surplus labour force in rural areas for development purposes. 'On the production side the movement strove to make farmers aware of new opportunities in the field of scientific agriculture and also to arrange for supply of modern inputs and supporting services'.[20] NES was responsible for introducing chemical fertiliser and improved seeds to the countryside. However, except for the establishment of a wide network of extension workers, the programme could not be claimed successful for a number of reasons.

---

20 Vyas, V.S. (1975) India's High Yielding Varieties Programme in Wheat, 1966-67 to 1971-72, Centro Internacional de Mejoramiento de Maiz Y Trigo, Mexico (p.2).

Mainly, a general lack of interest in the problems of common welfare among the mass of villagers was felt.[21]

The Intensive Agricultural District Programme (IADP) was launched in 1960-1 in seven districts which had high production potential and was subsequently extended to cover fifteen districts in different states. The objective of the programme was to demonstrate the potentialities for increasing food production through a coordinated approach based on concentrated and intensive efforts with the most effective package of improved agricultural practices and inputs for individual farm conditions, and to improve the input supply system, the extension service and district administration.

The area covered was 3.3 million hectares out of a total cultivated area of 8.8 million hectares in these districts. Consumption of fertilisers increased from an average of 7.9 kgs. per hectare in 1962-3 to around 20 kgs. in 1967-8. Total output of foodgrains in the IADP districts increased from an average of 5.8 million tons in 1958-61 to 7.2 million tons in 1967-8. However, the performance of IADP districts, on the whole, was not up to expectations. The IADP achieved its objective of a 50 per cent increase in food production by the end of the Third Five Year Plan Period (1961-66) in few districts. On the basis of a time-series study of yield and output, Brown showed that the IADP districts had gained neither more nor less output than the other districts not covered by IADP. In fact only 3 out of the 15 districts showed any significant improvement in agricultural production.[22] Studies of the IADP districts by Mellor showed that, except

---

21 Joshi, P.C. (1968) 'Community Development Programme: A Reappraisal', in A.M. Kushro (ed.) Readings in Agricultural Development, Allied Publishers, Bombay.

22 Brown, D.D. (1971) Agricultural Development in India's Districts, Harvard University Press, Cambridge.

for wheat, the programme did not bring about any significant change in productivity compared to other non-IADP districts.[23] Desai concluded that IADP districts did not perform well because of unorganised distribution of the scarce supplies of technical, financial and managerial inputs.[24]

The Intensive Agricultural Area Programme (IAAP) pursuing a similar approach and concentrating on specific crops, was introduced in 1964-5 on a more widespread scale in 115 districts throughout the country. By 1966-7, the IADP and IAAP together covered a total of 130 districts, 1721 blocks and 38.1 million hectares of cultivated area. The overall progress of the programme was not very encouraging if the increase in yield per acre is taken as the criterion. Both the IADP and IAAP were designed to promote intensive agriculture techniques, but they operated within limitations of existing adapted crop varieties which had relatively low response to fertiliser and other inputs. 'Other not-so-desirable features on the policy plane were lack of clarity in defining actual goals, in waivering between the extensive or intensive approach to the developmental tasks... The efforts though massive, and mostly in right directions, lacked sharp focus.'[25] Also, the absence of well suited price and research policies further aggravated the situation. As a consequence, a rapid breakthrough in agriculture for meeting the severe food scarcity was not achieved, and by 1966, the country was plainly in need of a well defined and different approach.

---

23 Mellor, J.W. et.al. (1968) Developing Rural India: Plan and Practice, Cornell University Press, Ithaca, New York.

24 Desai, D.K. (1972) 'Intensive Agricultural District Programme: Analysis of Results', in P. Chaudhri (ed.) Readings in Agricultural Development, Allen and Unwin, London.

25 Vyas, V.S. (1975) (p.3).

The Fourth Five Year Plan document observed that a new strategy should place very little reliance on bringing additional land under cultivation.[26] During the fifties, foodgrain production grew at an annual rate of 3.3 per cent, of which almost two-thirds was due to increased acreage and the remainder was accounted for by increased productivity. In the sixties, the annual growth rate of foodgrains was a lower 2.1 per cent of which only about one-third was due to increased acreage, while increased productivity accounted for two-thirds.[27] Thus for the Fourth Plan, with virtually no extension of cultivated area possible, a new agricultural strategy had to be found with the 'vertical restricted model'.[28] This was indicated by the propagation of new high yielding varieties of foodgrains in areas most favourably endowed with assured irrigation and supplies of chemical fertilisers, pesticides and extension personnel. This was called the New Agricultural Strategy of which the <u>High Yielding Varieties Programme</u> (HYVP) was the major field programme.

The HYVP was launched in kharif season of 1966 at field level, initially including five cereal crops: namely, rice, wheat, jowar, maize and bajra. In the beginning the programme was restricted only to areas with above average agricultural potential in order to achieve a rapid increase in yield, to close India's considerable food gap, and to produce

---

26 'The potentially usable area in the country is estimated at about 175 million hectares. Of this nearly 85 per cent is under cultivation. Thus there is a virtual exhaustion of uncommitted land resources.' [Government of India (1970) <u>Fourth Five Year Plan 1969-74</u>, Planning Commission, Government of India Press, New Delhi (p.121)].

27 Rao, C.H.H. (1975) <u>Technological Change and the Distribution of Gains in Indian Agriculture</u>, MacMillan, New Delhi.

28 In arguing for the restricted approach Desai observed that 'unless a strategy is evolved to combine the scarce resources of technical, financial and administrative inputs with the managerial inputs of the efficient farmers, rapid growth in agricultural production may not be achieved'. [Desai (1972) (p.154)].

a demonstration effect that would spread the programme across the whole country.[29]

Because of the previously slow rate of increase in foodgrain production and of food scarcity, which reached crisis proportions in two consecutive years of drought in 1965-6 and 1966-7, the HYVP was assigned a key role in the Fourth Plan. Out of a total increase of 31 million tonnes of foodgrains envisaged over the 5 years, 21 million tonnes were assigned to the HYVP.[30]

In the case of wheat, Mexican wheat varieties (Lerma Rojo, and Sonora-64), were released to cultivators as part of a package of inputs. These releases were preceded by varietal evaluations and successful field trials. For paddy varieties, Taichung Native-1 (TN-1), Taichung 65, Kalimpong-1, Taiwan-3 and others were imported from Taiwan, and later IR-8 and IR5 from the Philippines.[31] The Indo-Japonica, cross-bred variety ADT 27 was released in the southern states of Tamil Nadu, Kerala and Andhra Pradesh. It was classified as an HYV by the Central Varieties Release Committee (CVRC) on performance. Along with these wheat and paddy varieties, high yielding hybrid varieties of maize, bajra and jowar were

---

29 Mr C. Subramaniam, the ex-Minister for Agriculture, Science and Technology in India, responsible for introducing the HYVP in the 1960s argues that such choice of resource favoured areas was a political and economic imperative in the face of the alternative of high cost imports and growing external aid dependence. [Subramaniam, C. (1979) The New Agricultural Strategy: The First Decade and After, Vikas Publications, New Delhi].

30 Government of India (1974) Draft Fifth Five Year Plan 1974-79, Vol.II, Planning Commission, Government of India Press, New Delhi (p.1).

31 In the case of paddy 'administrative action preceded development of scientific knowledge'. [Swaminathan, M.S. (1969) 'Scientific Implications of HYVP Programme', Economic and Political Weekly, Vol.IV, Nos. 1&2, (pp.67-75) (p.69)].

also introduced effectively from 1966-7.[32] In support of the HYVP, the Indian Government undertook to make available the inputs needed, particularly fertiliser, by encouraging domestic investment in new factory capacity and by allocating foreign exchange to imports as needed. Agricultural research was reorganised and coordinated in a series of All-India schemes for raising productivity; extension services were intensified in the selected areas; credit needs of HYV adopters were recognised and various ways of providing credit were formulated.[33]

Because of the severe droughts in 1965-6 and 1966-7, it was not in fact until 1967-8 that the HYVP really got underway.[34] The total area under the HYVP was officially estimated to have increased from 6.0 million hectares in 1967-8 to around 38.8 million hectares in 1976-7. However, it has been observed that area covered by HYVs was being systematically

---

32 The hybrid maize, bajra and jowar had been developed in India with the assistance of the Rockefeller Foundation from 1957, 1964 and 1965 respectively.

33 Shand, R.T. (1976) 'The Green Revolution in India - a Decade and After', unpublished paper presented at a Work-in-Progress Seminar, Department of Economics, RS Pac S, Australian National University, Canberra.

34 During this and the following two years the Programme Evaluation Organisation (PEO) of the Indian Planning Commission undertook a series of nation-wide surveys to monitor the progress of the HYVP. In 1969 the Australian National University (ANU) became associated with the PEO in a joint research collaboration to analyse these surveys in depth, which resulted in a report published in 1971 [Lockwood, B., Mukherjee, P.K. and R.T. Shand (1971) The High Yielding Varieties Programme in India, Part I, PEO and ANU, Department of Economics, RS. Pac. S., Canberra]. In view of the significance of the HYVP for wheat and paddy, and of the rapidly changing situation, two more surveys were undertaken in 1973-4 and 1974-5 to examine the trends in the spread of the HYVP after 1970 and to assess the adequacy and timeliness of essential inputs and the constraints on further spread, which resulted the publication of a comprehensive study of the HYVP linking up with Part I in 1977. [PEO-ANU (1977) The High Yielding Varieties Programme in India 1970-75, Part II, Government of India Press, New Delhi].

over-reported, with wide unexplained differences between reported and actual coverage.[35] Thus, area coverage could not be relied upon as an indicator of progress of the HYVP. Also, area coverage could not show whether yield and output increases followed from the HYV adoption. Indeed, while official HYV area estimates for paddy showed marked increases over the Fourth Plan period, there was no corresponding growth in output.[36]

Total foodgrain output increased from 95 million tonnes in 1967-8 to 125.6 million tonnes in 1977-8. However, the increase in production was not steady and continuous throughout the period considered here. In 1968-9, the production of foodgrains was 94.1 million tons. It rose steadily to 108.42 million tons in the following two years, and the revised Fourth Five Year Plan target of 114 million tons in 1973-4 looked feasible.[37] However, the production at 104.7 million tonnes in that year proved to be well below the revised target of 114 million tonnes.[38] In the following year, it fell further to 101 million tons. Dasgupta argues that the period from 1971-2 to 1974-5 could be viewed as one of stagnation in the progress of the HYVP.[39] Nevertheless, 'it is significant that the preliminary estimate of foodgrain production of 95 million tonnes in 1972-3, despite widespread drought conditions, is more than 2.2-2.3 million tonnes higher

---

35 PEO-ANU (1977) Table 8 (pp.xxxiv).

36 Shand, R.T. (1976) (p.6).

37 Even this revised figure represented a high target. Annual targets were fixed at unrealistically high levels with little regard to local conditions and constraints. [PEO-ANU (1977) (p.xxi)].

38 These single year comparisons are of course open to question given the considerable year to year variability owing to climate. However, 1967-8 and 1973-4 were both generally favourable years climatically, so a broadly drawn comparison is reasonable. [Shand, R.T. (1976) (p.3)].

39 Dasgupta, B. (1977) Agrarian Change and the New Technology in India, UNRISD, Geneva (p.48).

than the output level attained in the drought years of 1965-6 and 1966-7. It is arguable if this level of production could be attained without the use of the high yielding varieties'.[40] Mellor used a different methodology for assessing the impact of the 'Green Revolution' on production and arrived at the conclusion that the production peaks as well as troughs were distinctly higher.[41] Considering two peak periods of production and calculating the compound annual growth rate of the years before the introduction of HYVP (1949-50 to 1960-1) and after the HYVP (1964-5 to 1970-1), he observed that the growth rate was 18 per cent higher in the latter period than in the former period.[42] From 1975-6, foodgrain production again rose to 125.6 million tons in 1977-8, an increase of 14.4 million tons over the preceding year (Table 1.2).

In the event, overall achievements fell short of targets for foodgrains from 1971-2 to 1974-5 and crop targets were met or exceeded only by wheat and bajra, and most notably by the former.[43] Thus by 1971-2, wheat production had reached a peak of 26.4 million tons, showing an increase of 10 million tonnes over a period of 5 years from 1967-8 and had exceeded the 1973-4 target figure. Its compound growth rate from 1967-8 to 1976-7 was

---

40 Sen, B. (1974) The Green Revolution in India: A Perspective, Wiley Eastern Private Limited, New Delhi, (p.15).

41 Mellor, J.W. (1976) The New Economics of Growth: A Strategy for India and the Developing World, Cornell University Press, Ithaca, New York.

42 Using similar methodology, Hanumantha Rao arrives at a somewhat different conclusion. [Rao, C.H.H. (1975)]. However, his conclusions were questioned by Dantwala on the grounds that the consequences of growth in foodgrains brought about via high prices and those resulting from the HYVP would be very different. [Dantwala, M.L. (1978) 'Future of institutional reform and technological change in Indian agricultural development', Economic and Political Weekly, Vol.12, Nos. 31,32&33, (pp.1299-1306)].

43 However, in later years, in 1976 and 1978, actual foodgrain production exceeded targets by 7.0 and 7.6 million tonnes respectively (Table 1.2).

TABLE 1.2

PLAN TARGETS AND ACTUAL PRODUCTION OF FOODGRAINS

Period	Foodgrain Production (million tonnes)		
	Targets	Actual	Excess (+) or Shortfall (-)
I Plan (1951-2 to 1955-6)	62.6	69.3	+ 6.7
II Plan (1956-7 to 1960-1)	81.8	82.2	+ 0.4
III Plan (1961-2 to 1965-6)	101.6	72.3	-29.3
1966-7	97.0	74.2	-22.8
1967-8	100.0	95.1	- 4.9
1968-9	102.0	94.1	- 7.9
1969-70	101.0	99.5	- 1.5
1970-1	106.0	108.4	+ 2.4
1971-2	112.0	105.2	- 6.8
1972-3	118.0	97.0	-21.0
1973-4	114.0	104.7	- 9.3
1974-5	118.0	99.8	-18.2
1975-6	114.0	121.0	+ 7.0
1976-7	116.0	111.2	- 4.8
1977-8	118.0	125.6	+ 7.6

Source: Directorate of Economics and Statistics (1974) Draft Fifth Five Year Plan 1974-79, Ministry of Agriculture and Irrigation, Government of India Press, New Delhi.

almost four times that of paddy over the same period (Table 1.3). Subsequently, wheat production has risen further to a peak of 31.3 million tonnes in 1977-8.[44]

By contrast, shortfalls of production in relation to targets were striking for paddy. It was proposed to raise production from a base level of 39 million tonnes during 1968-9 to about 52 million tonnes by the end of the Fourth Plan in 1973-4, but the increase achieved was not more than 5 million tonnes over the assumed base. Price showed a growth rate of only 1.9 per cent per annum for the Fourth Plan period, a substantial shortfall from the expected growth rate of 5.9 per cent.[45] Rice failed to play the leading role assigned to it in the Fourth Plan. Bajra was the only one of the three hybrid crops to show consistent and substantial increases in production during the period 1967-8 to 1976-7.

Overall, the major increases in total food production from 95 million tonnes in 1967-8 to 125.6 million tonnes in 1977-8 were largely due to increases in land productivity obtained through the HYVP. Narain observed that the 'pure yield effect' component increased significantly from 0.54 per cent in the pre-HYV period (1952-3 to 1960-1) to 1.33 per cent in the post-HYV period (1961-2 to 1972-3) in which the terminal year was a drought year.[46] 'Without the contributions of the new varieties to land productivity, and without any change in the country's socio-political structure, India in the late sixties and the early seventies could have

44 Output declined somewhat in 1974-5 and 1975-6 mainly because of the susceptibility of HYVs to rust. In more recent years, efforts made to breed HYVs with rust resistance have helped to increase wheat production (Table 1.4).

45 Lockwood, B., Mukherjee, P.K. and R.T. Shand (1971) (p.121).

46 Narain, D. (1977) 'Growth of productivity in Indian agriculture', Indian Journal of Agricultural Economics, Vol.32, No.1, (pp.1-31).

TABLE 1.3

GROWTH RATE OF FOODGRAIN PRODUCTION,
1967-8 TO 1976-7

Crop	Actual Compound Growth Rate 1967-8 to 1976-7 (per cent)
Paddy	1.53
Wheat	5.41
Pulses	0.30
All foodgrains	1.85

Source: Planning Commission (1978) Draft Five Year Plan 1978-83, Government of India Press, New Delhi (p.51).

TABLE 1.4

FOODGRAIN PRODUCTION, 1975-6 TO 1977-8

Crop	Production			Percentage Increase in 1977-8 Over	
	Average Annual Production During Five Years Ending 1975-76	1976-7	1977-8	1976-7	Five Years Average to 1975-6
Paddy	42.9	41.9	52.5	25.78	22.38
Wheat	25.2	29.0	31.3	7.93	24.21
Pulses	10.8	11.4	11.8	3.51	9.26
Other Cereals	26.6	28.9	29.8	3.11	12.03
Total Foodgrains	105.5	111.2	125.6	12.95	19.06

Source: Directorate of Economics and Statistics, Ministry of Agriculture and Irrigation, Government of India, New Delhi.

been visited by large scale starvation and famines.'[47] Thus, the application of a technologically based production strategy to the country's sluggish agriculture substantially paid off. 'The HYVs do appear to have made a distinct contribution to the maintenance of the growth rate of food-grain production (or arresting the decline) in the context of the declining contribution of the acreage growth rate, by accelerating the productivity growth rate.'[48]

Yet, the results of the HYVP have not equalled the intent. Three major observations can be offered on the performance of the HYVP since its introduction:

a. It was the growth in wheat output that has lately enabled the country to build up a substantial buffer stock.[49]

b. The programme succeeded in areas which were endowed with irrigation mainly. Other resources did not play a major role.[50]

c. Gains achieved in raising rice yields and output with the HYVP were consistently disappointing except in very limited areas.[51]

---

47 Dasgupta, B. (1977) (p.352).

48 Dantwala, M.L. (1978) (p.1300).

49 The main reason for the success of wheat HYVs was the adaptive research undertaken in wheat. This was relatively simple because the wheat producing areas are more or less continuous with a large degree of ecological and agro-climatic uniformity. Also, these areas were comparatively better developed in terms of infrastructure, particularly irrigation and were economically more advanced than paddy growing areas. [Vyas, V.S. (1975)].

50 Because of this, and the severe drought in 1972-3, the contribution of the HYVP did in fact fall during the period 1971-2 to 1974-5.

51 'For rice, the major initial problems have been associated with realising the high yielding potential of newly developed varieties under the widely varying conditions of production and market preference within the region.. Other problems were disease susceptibility, especially under conditions of high humidity and widespread market dissatisfaction with grain appearance...' [Shand, R.T. (1973) (p.285)].

The impact of the HYVP on income distribution and employment generation has been widely commented on. In areas where the HYVP has been successful in production terms, it has been argued that those who have primarily benefited are the richer and large farmers and that small farmers have been largely excluded. Ladejinsky observed, for example, in Punjab that 'owner farmers with irrigated land are making money hand over fist, and the bigger the farm the more they make... The new agricultural policy which has generated growth and prosperity is also the indirect cause of the widening of the gap between the rich and the poor'.[52] The exclusion of small farmers and landless labour from the benefits of the 'Green Revolution' was further criticised by Bardhan,[53] who observed that real incomes of these groups had failed to rise and their employment prospects had deteriorated in almost all states of India. Lewis[54] argued that though the new agricultural technology is not notably skewed toward larger-scale farmers, it is sharply skewed in favour of wet versus dry farming and concluded that the impact of the HYVP on income inequality will soon become dangerous to the economy. Comparing the performance of the new technology in Mexico, Taiwan and India, Raj[55] observed that the introduction of modern agricultural technology often creates dualism in the agricultural sector rather than modernising traditional agriculture. In answering

---

52 Ladejinsky, W. (1969) 'The Green Revolution in Punjab: a field trip', Economic and Political Weekly, Vol.IV, No.26, (pp.A73-82) (p.A73).

53 Bardhan, P. (1970) 'Green Revolution and agricultural labourers', Economic and Political Weekly, Vol.V, Nos. 29,30&31 (pp.1239-46).

54 Lewis, J.P. (1970) 'Wanted in India: a relevant radicalism', Economic and Political Weekly, Vol.V, Nos. 29,30&31 (pp.1211-26).

55 Raj, K.N. (1969) 'Some questions concerning growth, transformation and planning of agriculture in developing countries', Journal of Development Planning, Vol.I, No.1 (pp.15-38).

Raj's claim, Dantwala[56] argued in the context of the farming structure in India that, but for the HYVP, they would have remained below the subsistence level for a longer time and this situation must be preferred to a more 'egalitarian stagnation'. Johl[57] argues that income distribution in agriculture is mainly determined not by the technology but by the government fiscal policies and the results of defective fiscal policies reflected in more uneven income distribution. Dandekar[58] in this context, suggested a twin policy of regulating the capitalist sector in agriculture to protect hired labour and of taxing capitalist farmers sufficiently to enable the residual landless labour to be gainfully employed in creating capital and infrastructure for further agricultural growth. Shand[59] pointed out that the benefits from the HYVP even in areas where the HYVP has been successful in terms of area and production, cannot be said to be equally distributed. He concluded that for such areas, each farm gained in such a way as to leave its relative income position unchanged.

The above studies suggest that the factors affecting the impact of the HYVP on income and employment generation, may be placed under two headings: (i) physical-environmental; and (ii) institutional.

(i) Physical-environmental: In this regard, irrigation and drainage facilities have a great influence on the adoption of the HYVs. For lack of adequate

---

56 Dantwala, M.L. (1973).

57 Johl, S.S. (1973) Gains of Green Revolution: how they have been shared in Punjab, Department of Economics and Sociology, Punjab Agricultural University, Ludhiana.

58 Dandekar, V.M. (1970) 'Agricultural growth with social justice in over-populated countries', Economic and Political Weekly, Vol.V, Nos. 29, 30&31, (pp.1231-8).

59 Shand, R.T. (1978) 'Recent Indian experience of the international transfer of cereal grain technology', Development Studies Centre, the Australian National University, Canberra. (mimeo).

facilities the majority of rice growing areas are unable to participate in the HYVP.[60] For high yielding paddy varieties, water control is a complex and critical factor and both plenty and scarcity of water affect yield.[61] Thus long term investment on infrastructure, such as on irrigation and drainage facilities modifies the natural environment and enables less well endowed farming areas to participate in the programme. Another approach is to broaden the scope of scientific research to evolve HYVs that suit rain-fed and dry areas, i.e., that adapt the technology to better suit the existing environment rather than change the environment itself.[62]

(ii) Institutional: In this regard, input distribution, marketing, credit availability and extension advice are the important factors inducing participation. Proper functioning of institutions providing inputs, credit and extension work encourage small farmers, in particular, to grow HYVs, and it also determines the distribution of gains to a certain extent.

---

60 Hsieh, S.C. and V.W. Ruttan (1967) 'Environmental, technological and institutional factors in the growth of rice production: Philippines, Thailand and Taiwan', Food Research Institute Studies, Vol.7, No.3, (pp.307-41).

61 Barker, R. (1972) 'The economic consequences of the Green Revolution in Asia', in Rice, Science and Man, International Rice Research Institute, Los Banos, Philippines (pp.121-2).

62 Shand, R.T. (1978).

> But, to a greater extent, the distribution of benefits depends on the land ownership pattern. In the wake of the uneven distribution of land ownership, it becomes necessary to introduce institutional reforms which are conditional on the proper functioning of the factors mentioned above to bring a more even distribution of gains among the farmers. Thus, the distribution of benefits is indeed a problem of policy options on the part of government.

In short, as Dantwala[63] argued, a reasonable approach is for the government to bring about agricultural growth with social justice by giving priority to infrastructure investment and scientific research in areas with deficient endowments and to institutional reform in a technologically advanced area.

The Problem

The problem of paddy in the HYVP is of fundamental importance in India's quest for increasing food production. The performance of rice to date has been all the more disappointing in view of the considerable number of exotic HYVs (EVs) of paddy bred by the International Rice Research Institute (IRRI) in the Philippines that had been imported and released in India, and of the large acreages reportedly planted with them.

Experience showed that these varieties failed to approach their experimental yield potential under field conditions and frequently achieved

---

63 Dantwala, M.L. (1978).

yields below or barely matching those of existing local or local improved varieties. To a large extent these latter varieties were still preferred to the EVs. Even in 1975, for example, Mahsuri, a local improved variety was more popular than the EVs in many parts of Andhra Pradesh, Bihar, Karnataka and Kerala, because it was more disease-resistant than the available EVs, required less water, fertiliser and plant management and yielded fine grain and more fodder. This experience was similar to an earlier case of another local improved variety ADT-27, which performed as well or better than TN-1, in districts of the southern states of Andhra Pradesh, Kerala and Tamil Nadu.[64] Where yields of EVs were no improvement, and other characteristics were relatively unfavourable, farmers not surprisingly were unenthusiastic about adopting them, and either clung to or reverted to the known local or local improved (LIs) varieties.[65] Nevertheless, EVs did prove suited to limited areas, such as IR8, in part of northern India, and IR20 in Coimbatore district of Tamil Nadu.[66]

The reasons for the poor performance of EVs were soon appreciated. The important ones were the unsuitable duration of growing season and susceptibility to pests and diseases like gallmidge, brown plant hopper and tungro virus.[67] It was realised that it was not practicable to expect

---

64 PEO-ANU (1977) (p.35), (pp.39-40) and (p.167). On the basis of the performance, ADT-27 was classified as HYV by the Central Varieties Release Committee (CVRC) and similarly Mahsuri, by the State Government of Andhra Pradesh. They boosted figures of HYV area coverage in these states.

65 Dasgupta, B. (1977) (pp.65-7).

66 PEO-ANU (1977) (pp.36-7).

67 'In Thana district of Maharashtra state, for example, mid-duration varieties were found suitable for kharif season. However, lack of irrigation facilities and assured water in that season restricted their adoption to a certain water-retentive soil type, limited their yields and ruled out a second paddy crop. By contrast, the availability of suitable short and mid-duration HYVs and of assured irrigation water

these EVs to suit the widely varying production conditions in rice growing areas of India.[68] Prior to this realisation, the varietal breeding programme for rice in India was focussed on evolving a few widely adaptable HYVs that would provide large scale coverage throughout the country. The experimental breeding programme was largely based in Hyderabad and to a lesser extent in Cuttack though trials were conducted with promising new varieties in a wide variety of locations. With experience, rice research programmes in India began to undergo reorientation in the 1970s towards development of new varieties that utilised the high yielding potential of the EVs but which incorporated characteristics that would ensure adaptation to local conditions. These varieties are referred to in this study as location specific HYVs (LSVs).[69] As a consequence rice research efforts began to be decentralised, in locations representative of these local conditions of seasonal duration, of availability of irrigation water and of biological variation in pest and disease types.

---

67 (Continued)

for eleven months in Kodumudi block (Coimbatore district) in Tamil Nadu, placed it as the most intensively cultivated paddy area in the country'. [PEO-ANU (1977) (p.39)].

68 These production conditions refer to differences with respect to timing, duration, intensity and assurance of monsoons in various paddy growing areas and also to local growing conditions of topography, drainage, soils and availability of irrigation water. These factors produce a complex multiplicity of agro-climatic conditions for paddy cultivation which contrast with the prevailing, more or less homogeneous, production conditions in the wheat belt of North India.

69 In the early phase of the HYVP the plant breeders gave a high priority to yield potential without particular focus on pest resistance. Experience with the HYVP over a decade strongly underlined the need to give more attention to the evolution of pest resistant HYVs. However, this is not an easy task, as new varieties which are resistant to one type of pest are susceptible to other kinds. [Sen, S. (1974) <u>A richer harvest</u>, Tata-McGraw Hill, New Delhi]. Pests themselves adapt to selective breeding shortening the life-span of resistance and making the evolution of new resistant HYVs more difficult. [Chandler, R.F. (1973) 'The scientific basis for the increased yield capacity of rice and wheat', in T.K. Poleman and D.K. Fairbairn (eds.) <u>Food, population and employment</u>, Praeger Publications, New York].

The PEO-ANU surveys carried out in the first half of the 1970s identified a few areas in which adoption of HYVs had been widespread, where the input package was fully utilised, and where resulting yields were high. Survey data suggested that these areas were using LSVs well suited to local production and market conditions, i.e., where this new research emphasis had already progressed significantly. Given the importance of this new development for the New Strategy in Agriculture and for future foodgrain production in India, it was felt that this performance should be examined in depth to determine the extent and nature of success with this new approach of adapting HYVs of paddy to the range of production environments, and to explore the factors influencing the performance of what shall be called here the 'modified HYVP'. This study will therefore attempt to measure the gains and consequences for rice production from the evolution and introduction of LSVs. It is a comparative study of the performances of high yielding paddy varieties in an area where the initial introduction of EVs has been followed by the introduction and substantial adoption of LSVs. In order to judge the effect of removing this varietal constraint, and to assess better the field performance potential of the modified HYVP with such varieties, a study area was chosen in which other constraints are minimised, i.e., which approaches ideal field conditions for implementation of the programme. Indicators in the PEO-ANU surveys suggested that amongst areas surveyed, the district of Coimbatore in Tamil Nadu[70] was one of the most successful in terms of HYV area coverage and level of package inputs applied and was therefore chosen for this study to test the following main hypothesis:

70 PEO-ANU (1977) (pp.38-40).

Given the assurance of adequate input supplies including water, credit and extension, the introduction of LSVs under the new modified agricultural strategy would make a substantial physical and economic contribution to the field performance of the HYVP for paddy.

The specific objectives of this study therefore are to:

a. analyse the 'successful performance of the HYVP for paddy in Coimbatore district, Tamil Nadu, at farm level, taking account of the new emphasis given to location in varietal research and in dissemination of the new technology;

b. explore the factors affecting this performance; and

c. derive implications for policy to assist in the wider adoption of this modified version of the new technology.

Chapter Outline

The following chapter describes the study area, sampling technique used in the selection of sample participants, and the methods of data collection. The analytical framework of this study and the techniques used to analyse the framework are given in Chapter 3. The results of the empirical analysis of the comparative physical performance of location specific and exotic HYVs are presented in Chapter 4. In Chapter 5, the tests of economic efficiency of the sample participants growing LSVs and EVs are discussed. Chapter 6 examines the distributional aspects of the HYVP. The final chapter reviews the findings of earlier chapters and presents the important conclusions of the present study.

CHAPTER 2

STUDY AREA, DESIGN AND DATA COLLECTION

As discussed above, this is an economic study of recent developments in the HYVP for paddy, where new location specific high yielding varieties (LSVs) are replacing exotic HYVs (EVs) and local and local improved varieties (LIs). It is important to determine the comparative performance of these new varieties to be able to judge how the HYVP for paddy is likely to progress. Given limited resources of time and finance available, this could only be attempted by field survey method on a small scale, intensive basis.

A variety of approaches to the study were available. One would be to compare the experimental and field performance of different HYVs. A modified version of the 'constraints' approach of the International Rice Research Institute (IRRI) could accomplish this.[1] Another way would be to compare performances of HYVs under field conditions. Field comparisons can be made under two situations: (i) under favourable conditions where the performance in terms of varietal spread and yield impact is at a high level; and (ii) under limiting conditions where the adoption rate of newly released varieties is slow and yields are not markedly higher than the alternatives. Both approaches of experimental-farm and farm level studies would yield information that might then be more widely applied to enhance further the impact of the HYVP. But, for policy makers, farm level

1 IRRI's research work focuses on the yield difference between potential and actual farm yields which by their definition exists because farmers do not use inputs and practices at appropriate levels.

performance is more crucial as it bears directly on the development of the agriculture sector as a whole. Given the paucity of our current knowledge concerning the field performance of these new LSVs at farm level and of their possible contribution to the HYVP, it was decided to explore the question from the former view point, i.e., to analyse a 'successful performance'. This would allow some assessment of the absolute potential of the new LSVs and of the possible comparative gains over existing HYVs.

The following sections describe the sampling design and procedure used in this study, briefly discuss the choice of district, block, village and farmers and their characteristics, describe the ways and methods of data collection and, the nature and reliability of the data collected.

Sampling:

A three-stage purposive sampling procedure was first employed to select a sample village (Table 2.1). A progressive district, in terms of a high level of adoption of HYVs and high yields, was selected as a first stage. Blocks[2] in that district then were arranged in descending order of area conversion to HYVs of paddy, as measured by the proportion of total paddy area under HYVs in 1975. From there, a leading block was selected, as a second stage. For the third stage, villages within the selected progressive block were arranged in descending order of adoption of HYVs, using the same criterion, from which the leading village was selected.

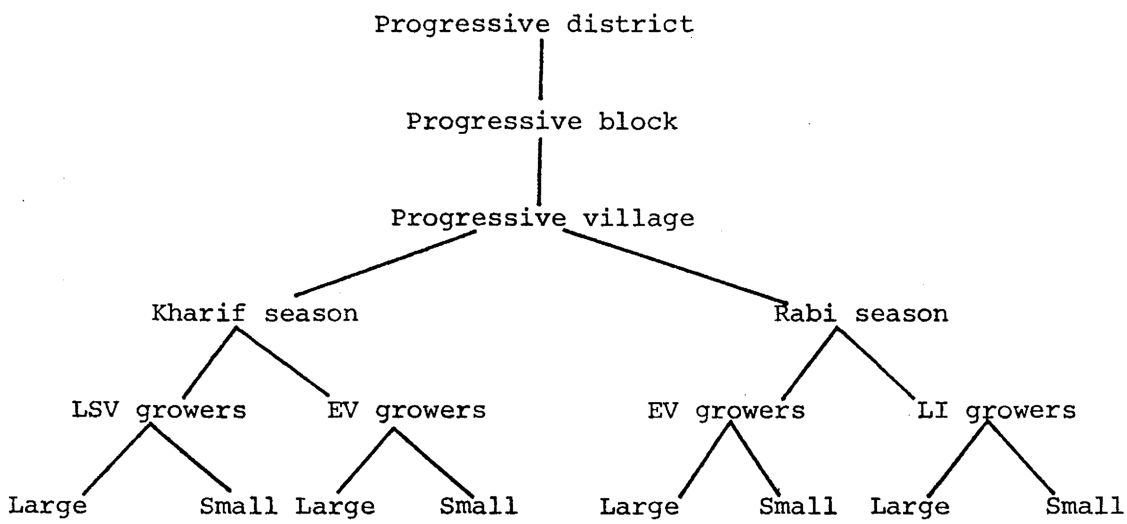
Selection of sample participants was made using stratified random sampling. For purposes of our study, farmers in the selected village were divided into different strata on the basis of varieties grown, season and

---

2 Blocks are administrative sub-divisions of a district.

TABLE 2.1

SAMPLE DESIGN



farm size, and selection was made at random of a predetermined number for each stratum.[3] As a first step, kharif and rabi seasons[4] were considered separately. Second, for each season, farmers were divided into two strata: those growing LSVs and those growing EVs.[5] Third, farmers in each varietal group were divided according to farm size into two categories - large (more than 1 hectare of operational holding) and small (less than 1).[6] Finally, a random sample of 25 was taken from each of the four sub-categories within

---

3 Sample size was predetermined because of limitations of survey time and finance available for this study.

4 Kharif and rabi refer to the summer (Apr.-Sept.) and winter (Oct.-Feb.) seasons respectively.

5 Information on growers by varieties was taken from the current list of farmers compiled by our survey investigators at the beginning of the season, by complete enumeration.

6 A pilot survey showed that in most of the villages about 50% of the farmers had operational holdings of 1 hectare. Accordingly, we attempted to give equal representation to both size groups. The operational holdings were not fragmented. There were both owner cultivators and tenants in the study area. Also see Page 56.

each season. Thus, the total of two groups of small and large farmers in a varietal stratum (e.g. LSVs), gives the total sample size of that stratum and the total of the two varietal sub-strata (LSVs and EVs) gives the total sample size selected by season for the study.

Choice of Survey Area:

Choice of survey area was assisted by the availability of particularly useful sources of information concerning recent progress of the HYVP, viz., the nationwide sample surveys conducted jointly by the Programme Evaluation Organisation (PEO) of the Indian Planning Commission and the Department of Economics, Research School of Pacific Studies of the Australian National University (ANU), the most recent of which was carried out in 1975,[7] and the crop yield surveys carried out by the Indian Agricultural Research Institute (IARI). The 1975 PEO-ANU survey and the yield statistics of the same year revealed a few districts in which the coverage of HYVs of paddy was high, measured in terms of the proportion of adopters amongst farmers, percentage of paddy area covered and HYV yield levels. These areas were favourably placed for the Programme in terms of irrigation, administration, paddy varieties etc. The PEO-ANU surveys further showed HYV area by varieties, which provided an opportunity to select an area for study where new LSVs had contributed to this coverage.

The 1975 PEO-ANU survey showed that two selected blocks in Coimbatore district in Tamil Nadu had amongst the highest levels of area coverage of HYVs of rice amongst their survey blocks.[8] Coimbatore also

7 PEO-ANU (1977).

8 These surveys selected a sample of farmers from each of three selected villages in the selected block.

showed the characteristics of successful matching of HYVs with local seasonal requirements in the form of LSVs. The commitment of paddy area to these HYVs by farmers, which was close to complete by 1974-5 in Coimbatore, was repeated in few other districts.[9] But, unlike most districts in which the HYVP participants grew both HYVs and LIs in a season, Coimbatore participants showed high proportions of growers cultivating only HYVs. The IARI yield statistics for the years 1970-1 to 1972-3 showed a high average yield of HYVs in this district.[10] Fertiliser inputs were also high for most participants in 1974-5 and exceeded recommendations for a considerable proportion of cultivators. In terms of the objectives of this study, these data on the HYVP performance for Coimbatore suggested that this district would be a suitable choice for a survey area.

Coimbatore District:

Coimbatore district in Tamil Nadu is bordered by the states of Karnataka to the north, Kerala to the west, and the Tamil Nadu districts of Madurai to the south and Salem and Tiruchi to the east. It has an area of 6,024 square miles and comprises four agricultural divisions - Coimbatore, Erode, Pollachi and Gobichettipalayam. Coimbatore is the only district in Tamil Nadu which combines agriculture with extensive large scale industrial activities. The pattern of land utilisation in the district in 1975-6 was as follows:[11]

9 PEO-ANU (1977) (p.39).

10 Ibid., (pp.83-5).

11 Unpublished official memorandum from the Office of the Deputy Director of Agriculture, Coimbatore.

	Acres
Total sown area (including area sown more than once)	1,514,369
Cultivable waste	39,647
Uncultivable waste	120,174
Forest	399,874
Permanent pastures and other grazing lands	15,835
Current fallow	160,665
Other fallow	73,009
Under miscellaneous use	9,360

Though about 60 per cent of its cultivated area is under food crops, the district has always been deficient in foodgrains. This is partly because of industrial development and partly because of the large areas under commercial crops such as cotton, sugar cane, tobacco and turmeric.

There are two main crop seasons in the district, kharif (August-December) and rabi (December-April), though a few areas with adequate irrigation do grow a third crop in summer, referred to as kharif II.[12] Area by crops in 1975-6 was reported as follows:[13]

Crop	Area in Acres	
	Kharif	Rabi
Paddy	248,482	115,596
Bajra	40,100	9,200
Maize	9,200	2,000
Jowar	336,908	128,624
Ragi	27,200	12,080
Cotton	14,050	160,349
Groundnut	180,900	6,930
Turmeric	7,050	3,100
Others	134,800	167,800
Total	908,690	605,679
Grand Total (both seasons)	1,514,369	

12 In 3 crop areas, the seasons are June to September, September-February and February-May.

13 Department of Agriculture (1976) Karutharanku Malar, Office of the Deputy Director of Agriculture, Coimbatore, (p.3).

Kharif is the most important crop season and has the largest paddy crop coverage. Paddy is an important but by no means predominant crop. Jowar, for instance, covers a larger area in both seasons. Paddy is, however, the most important irrigated food crop in the district. The district lies in a rain shadow region. The annual rainfall ranges from 25"-30" with 5"-12" falling during June to September (South West Monsoon) and 10"-15" during October to December (North East Monsoon). Though the district lies in a rain shadow area, it has a good surface water supply, as the Cauveri river and its tributaries the Bhavani, Amaravathi, Nayyal, Aliyar and Periyar rivers flow through it. The cropping pattern is controlled by the timing and availability of water, which varies with the source. Table 2.2 shows the sources of irrigation and the area irrigated in Coimbatore district. The data suggest that almost 60 per cent of sown area is irrigated by one source or another. Table 2.3 gives the area benefited by surface irrigation and the divisions to which they belong.

The major irrigation works serving the district are the Lower Bhavani Project, the Mettur Canal System and the Parambikulam-Aliyar Project. The Bhavani river has radically altered agriculture in the district, enabling paddy to be raised on a large scale. Two ancient ayacuts (distributaries) and a recent Lower Bhavani Project across the Bhavani, irrigated annually around 35,000 and 192,664 acres respectively. In the western part of the district the Mettur West Bank Canal serves about 17,000 acres. The Amaravathi Irrigation Project provides water for 20,000 acres and in addition there are more than a dozen small anicuts (artificial reservoirs) across the river Amaravathi serving a considerable acreage in total. The Nayyal streams serve about 13,000 acres through a

TABLE 2.2

SOURCES OF IRRIGATION, COIMBATORE DISTRICT, 1975

Source	Total Area Irrigated (acres)	Percentage to Total Area Irrigated
Tanks	16,406	1.81
Tube Wells	75	0.01
Open Wells	364,591	40.23
Surface (canals and channels)	525,125	57.95
Total	906,197	100.00

Source: Department of Agriculture (1975) Coimbatore district, Office of the Deputy Director of Agriculture, Coimbatore (p.27).

TABLE 2.3

SURFACE IRRIGATION BY SOURCE,

COIMBATORE DISTRICT, 1975

(acres)

Source	Area Benefited By Crops			Agricultural Division Benefited
	Triple Crop	Double Crop	Single Crop	
Lower Bhavani System	-	-	97,085	Erode
"			95,579	Gobichettipalayam
Mettur West Bank Canal	-	-	17,000	"
Amaravathi Project	-	-	21,500	Pollachi & Erode
Param Aliyar Project	-	-	240,000	"
Amaravathi Old Channel	-	15,533	-	"
Thadapalli Canal	-	28,428	-	Gobichettipalayam
Kalingarayan Canal	10,000	-	-	Erode
Total	10,000	43,961	471,164	

Source: As for Table 2.1 (p.28).

number of channels. Spring channels are utilised in some taluks and tanks and wells are filled by these during the rainy season.

The major proportion of soils in the district is red, sandy and gravelly. The other types found are black soils, (overlaying red calcareous soils), brown, alluvial and mixed soils. The district is topographically a plains area sloping towards the Bhavani river in the east and southeast. Therefore, drainage is not a problem for most areas and acidity and alkalinity are rare.

Coimbatore district is agriculturally well served by research institutions. Tamil Nadu Agricultural University (TNAU), soil, pesticides and seed testing laboratories, a regional research station of the IARI and a Sugar Cane Breeding Institute are the important ones located there. The district is fully covered by the Intensive Agricultural Area Programme (IAAP), which was introduced in 1963. It is also partly covered by other intensive programmes in cattle, cotton, banana, groundnut, and paddy under the HYVP.

The HYVP in Coimbatore District:

The HYVP was introduced to the district in kharif season of 1966. Before that, the district had been included in the IAAP, which had covered paddy, jowar, maize, cotton and groundnuts. There was a rapid growth of both HYV adopters and area under HYVs from 1966 in Coimbatore district. PEO-ANU Surveys reported that in 1974-5, there were only 4 amongst the sampled districts in which area coverage exceeded 50 per cent, and of these Coimbatore showed the best performance.[14] Participation by size of holding

14 PEO-ANU (1977) (p.30).

in Coimbatore district, showed increases in almost all size groups. In 1972-3, the PEO-ANU surveys showed there was little difference between small and large size groups in terms of grower proportions. The seasonal HYV coverages were of course highly dependent upon preferences amongst cultivators. Table 2.4 shows the HYV area coverage amongst the PEO-ANU sample participants by seasons for selected blocks in Coimbatore district from 1971-2 to 1974-5.

TABLE 2.4

HYV AREA COVERAGE AMONG SAMPLE PARTICIPANT FARMERS BY SEASONS FOR SELECTED BLOCKS IN COIMBATORE DISTRICT FROM 1971-2 TO 1974-5

Block	Season	Percentage HYV Area in			
		1971-2	1972-3	1973-4	1974-5
Gobichettipalayam	Kharif	92	92	88	100
	Rabi	87	84	86	88
Kodumudi	Kharif	68	90	81	95
	Rabi	100	100	100	100

Source: PEO-ANU (1977) (pp.158-59) and their unpublished primary data.

Varietal Choice: Prior to the IAAP period, TKM-6 was popular among local paddy strains. During the IAAP period, a local improved variety CO-32 was introduced and recommended along with TKM-6 for the first kharif crop in the Lower Bhavani System (LBS), and CO-29 was similarly introduced and recommended along with TKM-6 for the second kharif season. In the Amaravathi Project area, CO-32 and CO-19 were introduced. Before the introduction of ADT-27 (GEB-24 X Norin 6 or 8) in 1966, TKM-6 was the most popular variety among the farmers, and was preferred to the local improved varieties. In that year ADT-27 was introduced and soon replaced TKM-6 because of its higher yielding capacity and closer adaptation to the duration of the growing season. Indeed the ready acceptance of ADT-27 and other local improved varieties was responsible for the high proportions of HYV growers officially recorded in the district during the early years of the HYVP.[15] The first exotic HYV to be introduced was IR8 from the Philippines, and by 1970 this had displaced ADT-27. Further release of imported varieties from IRRI - IR20 in 1969-70, and subsequently IR22, IR24 and IR26 etc., slowly replaced IR8. By 1973-4, IR20 was the dominant exotic HYV with a little area devoted to two location-specific HYVs, CO-34 and Pusa 2-21.[16] Table 2.5 shows the evolution of varietal choice among PEO-ANU sample farmers in Coimbatore district over the period from 1970-1 till 1973 by percentage of area. Trends of adoption show that IR20 had the fastest growth in popularity and largely replaced IR8 which was unpopular owing to its susceptibility to pest and diseases, coarse grain quality, low fodder yield and unpalatability of its straw as cattle fodder. Of other recently introduced LSVs, CO-33 (Karuna) was said to have a high grain yield but suffered from low drought resistance, grain quality and fodder yield, and in 1972 was speedily loosing popularity. Though CO-34 also had low drought resistance and fodder yield, its higher yield, pest and disease resistance and shorter duration, resulted in its

---

15 It is debatable whether ADT-27 should be classified as an HYV. It was derived from a different breeding programme - the Indo-Japanese (FAO sponsored) cross breeding programme, using Indica and Japonica strains. A second and important strain evolved under this programme was Mahsuri, also called Ponni in Tamil Nadu.

16 CO-34, otherwise called Kanchi was derived by crossing T-141 with TN-1. Pusa 2-21 was a cross between TKM-6 and IR8.

TABLE 2.5

PERCENTAGE AREA UNDER LOCAL IMPROVED AND HYVs OF PADDY IN COIMBATORE DISTRICT FROM 1970-1 TO 1973 BY SEASONS

Variety	Year of Introduction	Percentage Area in					
		1970-1		1971-2		1972-3	
		K[a]	R[b]	K	R	K	R
Local Improved:							
CO-25	Before 1963-4	10	10	3	23	neg.	12
CO-29	"	18	15	19	11	16	11
Indica-Japonica:							
ADT-27	1965-6	32	17	20	9	14	5
Exotic HYV:							
TN 1	1966-7	-	-	-	-	7	-
IR 5	1967-8	2	3	2	4	-	-
IR 8	1967-8	38	55	31	19	2	9
IR20	1971-2	-	-	20	27	48	52
IR22	1971-2	-	-	1	5	7	5
LSVs:							
CO-33 (Karuna)	1971-2	-	-	3	2	2	1
CO-34 (Kanchi)	1971-2	-	-	neg.	neg.	4	5

Notes: a - K = Kharif season

b - R = Rabi season

Source: PEO-ANU (1977) - primary data.

adoption at a fast rate in 1974.

Input Supply and Distribution: New varieties brought into the district were first grown on state farms, then multiplied by registered growers and finally distributed through the agricultural depots attached to the blocks. Private seed growers supplemented state farm supplies to cultivators. Though in the initial stages of the HYVP, the supply of seeds was not adequate and timely, it did greatly improve later on.[17] Each of the six state farms had seed processing equipment from the beginning of the programme and there was also a seed testing laboratory which examined samples sent to it by state farms, and by Block Development Officers (BDO) who procured from private dealers on behalf of the Agriculture Department. The department pretreated seeds with Agrosan and supplied them to blocks. Until 1970, the periodic replacement of HYV seeds to maintain purity and vigour was not recognised as a necessity, for lack of publicity by the Agriculture Department, and consequent ignorance amongst cultivators. From 1970 onwards, there was reportedly an increasing appreciation amongst cultivators.[18] The pattern of water availability from the irrigation system greatly influenced the choice of paddy varieties. As in all paddy growing districts, Coimbatore depends on monsoons, but since the district lies in the rain shadow region of the Western Ghats, intensive cultivation has had to depend on provision of irrigation facilities from assured sources such as perennial rivers, and during growing seasons there is a heavy reliance on canal irrigation.[19]

Fertiliser requirements were estimated by the extension staff with the assistance of the District Soil Testing Laboratory. The District Collector who was the authority for receipt and distribution of straight fertilisers divided supplies into two categories of requirements; one for the HYVP and the other for normal programmes such as IAAP covering all crops. He also made special allotments on the basis of requests from the

---

17 PEO-ANU (1977) (p.68).

18 Annual report of the District Agricultural Officer, Coimbatore to the Deputy Director of Agriculture, Coimbatore, 1976.

19 PEO-ANU (1977) (p.55).

Deputy Director of Agriculture.[20] The supply of fertiliser was adequate and timely up to 1969-70 and the prices were kept in check by the Agriculture Department. From 1970-1 to 1972-3 shortages of fertilisers were not serious. They were most apparent in 1970-1 and, in general, for nitrogen fertilisers (pool) more than for phosphorous and potassic fertilisers (Table 2.6). In 1973-4, shortages became acute for N fertilisers.[21] However, in 1975-6, fertiliser availability and distribution satisfactorily met the needs of the cultivators in this district.[22] The Collector

TABLE 2.6

REQUIREMENTS AND SUPPLIES OF CHEMICAL FERTILISERS
IN COIMBATORE DISTRICT FROM 1970-1 TO 1972-3

Year	Requirements (m.tons)			Supplies (m.tons)		
	N	P	K	N	P	K
1970-1	33126	16468	14581	27679	10430	9354
1971-2	34624	11285	16809	29826	11339	10353
1972-3	39360	17285	16809	34214	15054	13676

Source: PEO-ANU (1977) - primary data.

allocated supplies to the distribution points, which were mostly co-operatives, on the basis of requirements reported by DAOs. The district was well served with distribution points, both co-operative and private. To facilitate quick distribution of fertilisers there were 15 sales or

20 Ibid., (p.71).

21 Ibid., (p.71).

22 Department of Agriculture (1976) (p.28).

marketing societies at district level with about 215 distribution points in 1976. There were in addition, about a dozen private companies with nearly 200 distribution points in the district.[23]

In Coimbatore district, the orders for supplies of plant protection materials were placed by the Director of Agriculture and supplies were stored in the Block Depots for distribution to cultivators. They were also distributed by primary societies which gave loans to participants.[24] Private agencies were also active in supplying chemicals to farmers. The PEO-ANU Surveys reported that by 1968-9, the use of prophylactic measures was widespread for the crop. During 1970-1 and 1971-2, chemicals were not in short supply and there was only a marginal gap between total quantities required and consumed.[25] The Agriculture Department supplied equipment for application of pesticides not only to depots, panchayats and co-operatives, but also to individual farmers. Village institutions hired out the equipment, for which maintenance services were made available by the block authorities.[26]

Timely availability of credit is of great importance for the success of the HYVP. There were three main sources of credit for meeting cultivation expenses in Coimbatore district - the village Primary Co-operative, the nationalised banks and the Revenue Department (in kind only) under the Intensive Manuring Scheme. Annual loans were estimated by Co-operative Officers and issued for each season with the requirement of

---

23 Information supplied by the Fertiliser Inspector, Office of the District Agricultural Officer, Gobichettipalayam.

24 PEO-ANU (1977) (p.73).

25 Information supplied by the Plant Protection Officer, Office of the District Agricultural Officer, Gobichettipalayam.

26 PEO-ANU (1977) (p.73).

repayment or recovery at the end of the season and before disbursement for the next season. Cultivators, however, favoured full repayment of all seasonal loans at the end of the succeeding crop season.[27] In 1972-3, the maximum loan issued by the co-operatives was Rs. 600 per acre for HYV growers, and Rs. 360 per acre for local improved varieties.[28] There were a number of agencies serving short, medium and long term credit needs in the district (Table 2.7). Private money lenders played an important role in advancing loans to small and tenant cultivators. One way or another, farmers in the district were able to obtain adequate loans in time.

TABLE 2.7

SOURCES OF AGRICULTURAL CREDIT BY TYPE AND PURPOSE IN COIMBATORE DISTRICT DURING 1972-3

Type and Purpose of Loan	Agencies
Crop Loan (short term)	(a) Central Co-operative Bank (b) Agriculture Department (c) Commercial Banks (d) Private Agencies (e) Block
Farm Capital Loans (short and medium terms)	(a) Central Co-operative Bank (b) Land Development Bank (c) Agriculture Department (d) Commercial Banks (e) Private Agencies (f) Block
Loans for Heavy Agricultural Machinery (long term)	(a) Land Development Bank (b) Agriculture Department (c) Commercial Banks (d) Private Agencies

Source: Compiled from various reports of the Office of the Deputy Director of Agriculture, Coimbatore.

27 PEO-ANU (1977) (p.59).

28 Information from the primary data, PEO-ANU Surveys.

One of the major findings of the PEO-ANU Surveys was the general inadequacy of staffing for administration and technical guidance in the HYVP. Coimbatore district, too, had problems of this kind with its high levels of participation.[29]

Implementation of the HYVP at district level, besides technical training and guidance required:[30]

a. the selection of areas and participants for inclusion;

b. formulation of farm plans and calculation of input needs of the HYVP including credit;

c. arranging the supply and distribution of these inputs;

d. coordination of departmental activities associated with the programme; and

e. maintaining records and statistics as a basis for periodic reports on the HYVP.

These requirements indicate that the Agriculture Department has the heaviest responsibility for administration of the HYVP. Targets for the district and divisions were communicated by the Director of Agriculture to the Deputy Director of Agriculture and to the District Agricultural Officers (DAOs) who prepared estimates of requirements of seeds, fertilisers and pesticides for the targetted area. The DAOs split the divisional targets on a block basis and set these and fertiliser requirements to the Block Development Officers (BDOs). The BDOs then split block targets on a village basis. Cultivators were selected and farm plans prepared for them.[31] The DAOs were also expected to provide technical assistance through extension advice.

---

29 PEO-ANU (1977) (p.65).

30 Ibid., (p.64).

31 Ibid., (p.66).

The PEO-ANU Surveys reported interestingly that target setting in this district at lower levels was not rigid, as was the case in the majority of the survey districts. In spite of the drawbacks of inadequate staff, the programme was well sustained by the initiative and enthusiasm shown both by the farmers and extension staff. The Agriculture Department also engaged in publicity work by promoting the HYVP through radio, press and mass meetings etc. Both varietal and manurial trials were undertaken by the Agriculture Department and Tamil Nadu Agricultural University (TNAU) on a regular basis after 1970.

On the research side, a long term programme of cross-breeding and selection work had been undertaken at TNAU over a 10 year period directed towards the identification and definition of local agro-climatic zones, and of matching HYVs to these areas. Results of this research, discussed below, underscore its contribution to the HYVP in this district.[32]

Input Application: Table 2.8, based on the PEO-ANU primary report, shows that actual usage of fertiliser inputs per hectare did not vary greatly from the cultivator's own norms, which in turn were generally higher than the official recommendations. Coimbatore was the only selected district in the PEO-ANU Surveys in which fertiliser dosages rose substantially from 1972-3 to 1974-5 despite a steep increase in their prices.[33] The reason appeared to be the continued high market price for paddy obtained by cultivators, arising from the deficit in foodgrains in the district. From 1972-3 to 1974-5, most selected districts showed great variation in fertiliser application by size of holdings. Coimbatore was one of the few exceptions.[34]

---

32 Ibid., (p.40).

33 Ibid., (p.48).

34 Ibid., (p.43).

TABLE 2.8

AVERAGE USE OF CHEMICAL FERTILISERS ON HYVs OF PADDY, THE CULTIVATORS' OWN NORMS AND THE OFFICIAL RECOMMENDATIONS IN COIMBATORE DISTRICT BY SEASONS, 1974-5

Fertilisers	Application per Acre (Kgs.)					
	Actual		Own Norm		Recommended	
	K[a]	R[b]	K	R	K	R
Nitrogen	43	41	45	40	40	40
Phosphorous	22	22	22	22	20	20
Potassium	22	20	22	20	20	20
Total	87	83	89	82	80	80

Notes: a - K = Kharif season

b - R = Rabi season

Source: PEO-ANU (1977) - primary data.

Protection measures for HYVs of paddy proved to be an important part of the package of inputs from the inception of the HYVP as the initial varieties suffered attacks from pests and diseases. In Coimbatore from 1970 to 1973, use of both preventives and curatives declined owing to shortages of materials. In the 1973-5 period, preventives were not applied at all and curatives were used only after attacks or symptoms showed.[35] Coimbatore was reported to be a district that experienced a generally low incidence of pests and diseases and was active in taking plant protection measures which were close to the recommendations.[36]

35 Ibid., (p.50).

36 Ibid., (p.51).

Amongst the fourteen survey districts, Coimbatore was one of only two with low proportions of credit overdues. It was interesting to observe that the cultivators in Coimbatore had the will and sense of discipline to repay the loans in time. In fact defaulters were looked down upon by fellow cultivators and this was reported to have been the principal factor contributing to the high percentage of recovery of dues.[37]

Summing up, the causes for the high level of adoption of the HYVP by the farmers in Coimbatore district can be described as:

a. assured and adequate water supply mainly from the surface irrigation sources;

b. the contribution of the paddy breeding station at the TNAU which is engaged in continuous evolution of HYVs more suitable to local environments;

c. easy access to and availability of major inputs including credit;

d. involvement of very low yield risk and price risk with the HYVs;

e. enthusiasm of the farmers growing HYVs along with high literacy levels among family members; and

f. relatively good administration and technical guidance provided by the Agricultural Department.

Block Selection:

Gobichettipalayam (Gobi) registered the highest proportion of paddy area under HYVs amongst the blocks in Coimbatore district.[38] This

37 Ibid., (p.59).

38 Information supplied by the District Agricultural Officer, Coimbatore.

block[39] is situated at a distance of about 91 kilometers to the northeast of Coimbatore town. One of the fertile areas in the district, the block comprises 25 panchayats[40] covering 32 revenue villages and 188 hamlets. The major occupation of the population is agriculture and the pattern of land utilisation in the block in 1975-6 was as follows:[41]

	1975-6 (acres)
Total cropped area	25,018
Net cultivated area	19,656
Area sown more than once	5,362
Barren and uncultivated land	300
Cultivable waste	620
Current fallow	1,132

Area by crops in the block in 1975-6 were as follows:[42]

Crop	Area (acres)
Paddy	9,819
Jowar	3,893
Ragi	782
Maize	33
Bajra	1,014
Groundnuts	3,903
Sugar cane	4,538
Cotton	1,036
Total	25,018

39 Kodumudi was the only block in which three irrigated crops were grown per year as water was guaranteed for 11 months. Gobi was preferred to Kodumudi as being more typical of irrigated areas in the district and elsewhere.

40 Panchayat is an administrative sub-division of a block.

41 Information supplied by the Block Development Officer, Gobichettipalayam.

42 Information supplied by the Office of the District Agricultural Officer, Gobichettipalayam.

The landscape is uneven with slight undulations and there are no serious drainage problems. Soil type is principally red loamy. The block, like the district is located in a rain shadow region which benefits little from the southwest monsoon. It receives most rainfall from the northeast monsoon particularly during October and November (Table 2.9). The main sources of irrigation for the block (Table 2.10) are the Thadapalli Canal[43] and Lower Bhavani Project System (LBPS). The Thadapalli Canal receives water for 10 months, usually released from 15th April to 15th February, permitting two paddy crops a year. In LBPS, water is released in turns; from August to December for the 'first turn' in which paddy is grown, and from January to April for the second, in which other crops are grown.[44]

The HYVP and Gobichettipalayam Block: The PEO-ANU report showed that in 1974-5, there were only 4 of 27 selected blocks in which HYV area had reached proportions above 75 per cent of total paddy area, and Gobi block was one of these.[45] Among HYVP participants in kharif season, in Gobi block, the majority grew only HYVs. IR20 became the dominant kharif HYV and indeed was sown almost exclusively in this block in 1974-5.[46] From 1974-5 onwards, it was grown exclusively in rabi season too in a majority of areas in the block.[47] From 1974-5 in kharif season, more recent varietal releases (LSVs) ADT-31 and CO37 shared the HYV area with IR20.[48]

---

43 Thadapalli Canal receives water from a diversion dam across the Bhavani river at Kodiveri near Gobi town.

44 Information supplied by the District Agricultural Officer, Gobichettipalayam.

45 PEO-ANU (1977) (p.156).

46 Ibid., (p.36).

47 Annual report of the HYVP from the District Agricultural Officer, Gobichettipalayam to the Deputy Director of Agriculture, Coimbatore, 1977.

48 Ibid., (p.10).

TABLE 2.9

RAINFALL IN GOBICHETTIPALAYAM BLOCK BY MONTH, 1970-75

Month	Rainfall (mm.)					
	1970	1971	1972	1973	1974	1975
January	28.5	72.9	-	-	-	-
February	11.7	3.3	-	-	-	-
March	-	64.3	-	21.8	19.2	13.9
April	42.4	7.1	67.8	178.6	53.8	16.7
May	90.2	61.7	197.4	134.1	32.0	96.4
June	7.6	16.2	59.5	49.8	23.7	23.2
July	30.2	55.6	5.9	86.9	80.9	95.1
August	47.1	163.8	35.1	76.3	80.9	87.2
September	22.0	175.4	223.0	96.7	25.3	50.3
October	277.1	151.4	383.3	200.3	254.5	302.2
November	108.2	60.7	461.3	40.5	29.3	164.7
December	-	17.6	84.3	23.6	1.3	12.7
Total	665.0	849.71	1517.6	908.6	600.9	812.1

Source: Various reports of the Office of the Block Development Officer, Gobichettipalayam.

HYV seeds were supplied through the Agricultural Depot and private dealers. In 1975-6, chemical fertilisers were distributed through the 16 co-operatives and 72 private dealers in the block.[49] Pesticides were distributed through the Agricultural Department go-downs and by private dealers, of which there were 19 in 1975-6.[50]

Farmyard manure and compost applications were generally higher than the official recommendations, but were equal to the cultivators' own

49 Information supplied by the Block Development Officer, Gobichettipalayam.

50 Ibid.

TABLE 2.10

SOURCES OF IRRIGATION IN GOBICHETTIPALAYAM BLOCK, 1977

Source		Area (acres)	Percentage
Thadapalli Canal		5,773.43)	
LBPS	1st	3,473.60)	81.1
	2nd	4,478.80)	
P. Mettupalayam Tank		154.80	0.9
Metkupalayam Wells		3,096.00	18.0
Total		16,976.63	
Total number of wells		2,975	
Total number of electric motors		2,520	
Total number of oil engines		485	

Source: Information supplied by the Gobichettipalayam Panchayat Union Office, Gobichettipalayam.

norms in Gobi block from 1972-3 to 1974-5.[51] Chemical fertilisers and plant protection chemicals were applied at levels close to official recommendations in the block.

Village Selection:

Seyyampalayam[52] village in Gobi block was selected as the study area, as it had the highest percentage of paddy area under HYVs in both seasons. More specifically, in kharif 1975-6 and 1976-7 HYV area coverage

51 Cultivators' own norms refer to their personal beliefs about the best dosage. This may be greater or less than the recommended dosage. This may also be greater than the actual dosage if the inputs are unavailable or the farmer cannot afford them.

52 Data on Seyyampalayam used in this section were compiled from various reports from the Office of the District Agricultural Officer, Gobichettipalayam.

in this village was complete, and in rabi season it reached 90 and 95 per cent respectively in these two years.

Seyyampalayam is situated about 10 kilometers southeast of Gobi town. It is fully irrigated by the Thadapalli Canal and raises two paddy crops per year. The net sown area in 1976-7 was 361 hectares. Paddy is the only crop cultivated in this area. Seyyampalayam receives good rain during the northeast monsoon, in the months of October and November, particularly.

The kharif season commences with the release of water from the Thadapalli Canal in the middle of April, and extends up to the middle of September. The rabi crop is raised in October, and is harvested in late February. From 1972-3 to 1974-5, IR20 was grown almost exclusively in both seasons in this area. In 1973-4, a small percentage of paddy area in kharif was devoted to the LSVs CO-34 and CO-36. In 1975-6, two more recently released LSVs ADT-31 and CO-37 were also planted on a small proportion of area in kharif season in Seyyampalayam village. In 1976-7, the percentage of area under these latter had expanded in kharif, as growers had found them suited to local production conditions. They out-yielded and replaced CO-34 and CO-36, and similarly performed better than IR20 in kharif season. In rabi season, however, IR20 retained its popularity and was grown by a majority of the farmers in Seyyampalayam throughout the reference period (Table 2.11).

A variety of organic and inorganic nutrients were used by farmers in Seyyampalayam. Farmyard manure, consisting of cow-dung, ash and other kinds of refuse and sweepings were used widely together with compost. Green manures, in the form of leaves from trees and plants specially grown

TABLE 2.11

PROPORTION OF HYV AREA UNDER EVs, LSVs AND LIs
BY SEASON IN SEYYAMPALAYAM VILLAGE FROM 1972-3 TO 1976-7

Variety	Type of Variety	Percentage Area in									
		1972-3		1973-4		1974-5		1975-6		1976-7	
		K[a]	R[b]	K	R	K	R	K	R	K	R
IR20	EV	80	60	82	61	84	60	78	62	50	65
Bhavani	EV	10	12	10	15	9	14	7	10	8	9
IR22	EV	6	-	1	-	-	-	-	-	-	-
CO-29	LI	-	-	-	2	-	8	-	7	-	6
CO-25	LI	-	15	-	10	-	12	-	13	-	10
Ponni	LI	-	3	-	2	-	6	-	8	-	10
CO-34	LSV	-	-	2	-	3	-	2	-	-	-
CO-36	LSV	4	-	5	-	4	-	3	-	-	-
CO-37	LSV	-	-	-	-	-	-	5	-	20	-
ADT-31	LSV	-	-	-	-	-	-	5	-	22	-
Total HYV	EV & LSV	100	72	100	76	100	74	100	72	100	74

Notes: a - K = Kharif season

b - R = Rabi season

Source: Compiled from various reports of the Office of the District Agricultural Officer, Gobichettipalayam.

for this purpose were also quite commonly used in the study area. From 1974-5, a majority of farmers in Seyyampalayam used overall more than recommended levels of chemical fertilisers. Table 2.12 shows the average application of the fertilisers per acre by farmers in Seyyampalayam in 1975-6. In 1976-7 the proportion of cultivators applying more than recommended levels of chemical fertilisers was 78 per cent. In that year, almost all the farmers in the village took preventive and curative measures

TABLE 2.12

APPLICATION OF PLANT NUTRIENTS PER ACRE BY FARMERS IN SEYYAMPALAYAM VILLAGE BY SEASONS, 1975-6

Type of Nutrient	Name of Nutrient	Application per Acre (Kgs.)	
		Kharif	Rabi
Organic fertiliser	Farmyard manure (in 400 Kgs.)	12	10
	Green manure (in 10 Kgs.)	6	5
Inorganic fertiliser	Nitrogen (Kgs.)	51	47
	Phosphorous (Kgs.)	23	22
	Potassic (Kgs.)	22	23

Source: Compiled from the Annual Report of the HYVP from the Office of the District Agricultural Officer, Gobichettipalayam to the Office of the Deputy Director of Agriculture, Coimbatore, 1976.

of plant protection. From 1974-5, Brown Plant Hopper (BPH) attacks on HYVs, mainly on IR20, were reported with heaviest incidence in 1976-7.

The proportion of pure tenants amongst total farmers in Seyyampalayam in 1975-6 was only 5 per cent. A further 12 per cent were cultivating both owned and leased-in lands and the rest were owner cultivators.

Data Requirements: For the purposes of statistical analysis, it was initially hoped to fix the sample size at 100 for each season. This did not prove possible since, of the total of 243 farmers in Seyyampalayam village, only 41 were growing EVs in kharif and the rest were growing LSVs. Thus the desired number of 50 EV growers could not be reached. It was therefore decided to include all farmers growing EVs in kharif, and to treat this group as a sample from a hypothetical population for the purpose of applying statistical tests.

A random sample of 50 was taken from the list of LSV growers. Fortunately, the 41 EV growers were divided roughly evenly between small and large farmers (21 and 20 respectively). The total sample size in kharif season was therefore reduced from the desired 100 to 91 or 37 per cent of all village farmers (Table 2.13).

For rabi season, difficulties were again encountered in selecting the desired numbers growing local and local improved varieties (LIs).[53] Only 21 farmers in Seyyampalayam grew LIs in rabi season; so again, all of them were included in the sample. Unfortunately, with the exception of 3, all were small farmers. With no shortage of EV growers in this season, the sample size of these growers could be increased from 50 to 70, with equal proportions of large and small cultivators. The total rabi sample size was therefore again 91 (Table 2.14). However, these 91 farmers selected were different from the 91 farmers selected in kharif season.[54]

Data Collection:

Data collected were: (a) Primary, obtained by direct interview, using both quantitative and qualitative questionnaires (Appendix 2.1-2.3) on all key aspects of the rice production cycle in each season; (b) Secondary, comprising reports and other information from government, experiment stations and various departments and institutions.

(a) Primary data, collected by interviews, comprised information from: (i) sample farmer interviews which provided cross-sectional data by size of farm, paddy variety and season; (ii) agricultural officials including the Deputy Director of Agriculture, District Agricultural Officer, Block

53 In rabi season, only EVs and LIs were grown and LSVs were not grown.

54 It may be noted that 79 and 81 of the sample participants were owner cultivators respectively in kharif and rabi seasons. The rest (12 in kharif and 10 in rabi) were tenant cultivators on long term (25-30 years) agreement. A preliminary statistical test between the owner and tenant cultivators in the use of inputs per acre, and yield obtained turned out to be insignificant, (Appendix 2.5).

TABLE 2.13

DISTRIBUTION OF ALL FARMERS AND SAMPLE FARMERS IN SEYYAMPALAYAM VILLAGE BY CHOICE OF HYV AND SIZE OF HOLDING, KHARIF SEASON, 1977

Size of Farm	Total No. of Farmers Growing		Sample Size		Sample Average		
	LSV	EV	LSV	EV	Family Size	Operated area (ac)	Farm Income per ac. (Rs.)
Small (Below 1 hectare)	100	21	25	21	4.1	1.51	3525
Large (1 hectare and above)	102	20	25	20	5.3	6.67	3821
Total	202	41	50	41			

TABLE 2.14

DISTRIBUTION OF ALL FARMERS AND SAMPLE FARMERS IN SEYYAMPALAYAM VILLAGE BY CHOICE OF PADDY VARIETY AND SIZE OF HOLDING, RABI SEASON, 1977-8

Size of Farm	Total No. of Farmers Growing		Sample Size		Sample Average		
	LSV	EV	LSV	EV	Family Size	Operated area (ac)	Farm Income per ac. (Rs.)
Small (Below 1 hectare)	18	103	18	35	4.6	1.51	2723
Large (1 hectare and above)	3	119	3	35	5.7	5.94	3021
Total	21	222	21	70			

Development Officer, the Agricultural Extension Officer, Deputy Agricultural Officers and the Secretary of the Village Co-operative Society. A mass meeting of the participants were arranged at the beginning of the survey to describe the nature and importance of the study. It was attended by 69 of the 91 selected farmers. The Deputy Director of Agriculture[55] was interested in the study and through the District Agricultural Officer and village karnam (a revenue officer), requested the farmers (and concerned officials) to give their maximum co-operation to our project. The sample participants proved co-operative over the full period of the survey (June 1977 - March 1978), and no serious difficulties were encountered with this source of data.

The data collection by interview of participant farmers was done by the author with the assistance of two full time investigators. One educated member from each selected farm household was appointed as recorder and was responsible for completing the 'Activity Schedule' (Appendix 2.4). These schedules were subjected to periodic checks for consistency and accuracy by the investigators and the author. The team mostly interviewed in Tamil, the regional language, except with those cultivators who could use English. The answers were written in English by the team.

Besides selected farmers, a number of officials were also interviewed. The DD of Agriculture, who is in charge of agricultural programmes at the district level, was asked about the performance of the HYVP for paddy in the district and about problems with it, and his department's approach to those. Similar questions were posed to the BDO at block level.

---

55 Mr C. Manimanthiri was the Deputy Director of Agriculture, Coimbatore during the period of our study.

At village level, the responsible officer, Dy AO and AEO were questioned about farmer response to recommendations concerning cultural practices and other field aspects of the HYVP. Discussions were held with Dy AOs concerning the distribution of chemical fertilisers, HYV seeds, and pesticides and with officials of the financial institutions, about credit supplies to cultivators.

(b) Secondary data about the characteristics of the district and the evolution of the HYVP for paddy in the district were collected from government departments, the agricultural university and other institutions as follows:

(i) Paddy Breeding Station, Tamil Nadu Agricultural University, Coimbatore;

(ii) Experimental Station, Bhavani;

(iii) Soil Testing, Seed Testing, and Pesticides Testing Stations, Coimbatore;

(iv) Office of the Deputy Director of Agriculture, Coimbatore;

(v) Statistics Department, Government of Tamil Nadu, Coimbatore;

(vi) Office of the District Agricultural Officer, Gobichettipalayam;

(vii) Panchayat Union Office, Gobichettipalayam;

(viii) Taluk Office, Gobichettipalayam (Statistics Division);

(ix) Office of the village Karnam, Seyyampalayam; and

(x) The Co-operative Society, Lakkampatti (serving Seyyampalayam).

Reliability of Data: "The accuracy obtained in a survey needs to be measured, not against a standard of absolute precision, but in terms of 'tolerable' limits to the error that would make the data 'usable' for the objectives in hand."[56] The possibility of errors arising in the process of data collection may be the fault either of participants, investigators or both. The sample participants may misunderstand the question or offer misleading answers. In the former case, it is the responsibility of the interviewer to explain the questions adequately to the farmer. He can apply cross-checks to test the consistency of the farmers' answers.

Nearly 20 per cent of sample participants in this survey, used to keep farm records, which greatly assisted data collection. For the rest, the appointment of recorders helped to generate clear and correct information on field activities and inputs. These recorders were mostly high school students and were recruited with the assistance of school staff, who helped to ensure that the students took a responsible approach to recording work. Periodically, in addition to the cross-checks built in the questionnaires, consistency of responses was checked. Farmers' estimates of total output, for example, were checked by adding the amount given in kind to land-lord (if any), to the labourers, kept as seeds and for personal consumption and the amount sold. These data were collected not only from the cultivator but also from the persons receiving them. Thus the paddy price received by the cultivator was checked with the help of the trader who bought from him.

56 Chinnappa, B.N. (1974) 'A note on the accuracy of data collected in the survey', paper presented in the seminar on Project on Agrarian Change in Rice Growing Areas of Tamil Nadu and Sri Lanka, St. John's College, Cambridge, 9-16, December (p.1).

The possibilities of the investigators making mistakes in filling up the questionnaires were minimised by exchanging the filled out questionnaires between the investigators for checking. All the combined schedules were thoroughly checked, and every day after coding, a fairly thorough check was made on the coded sheets by the author. On completion of the coding of all schedules, the sheets were checked once again. With transfer onto magnetic tapes, data were subject to further checks by the computer (DEC 10) by the use of a programme of logical checks which assigned minimum and maximum values for a variable, etc. Thus care was taken at every stage to minimise errors.

CHAPTER 3

ANALYTICAL FRAMEWORK AND TECHNIQUES

The extent to which the location-specific HYVs of the modified HYVP represent an improvement is determined by their performance compared to existing HYVs in the HYVP. A technological improvement has to be judged both in terms of physical and economic criteria, i.e., the modified HYVP can be judged successful only if it satisfies a number of criteria:

a. Within the context of the existing agricultural infrastructure, the LSVs, introduced through the modified HYVP, increase land productivity by raising yields (physical performance).

b. They raise profits per acre (monetary performance).

c. Within the context of the existing input supply systems, their benefits of higher yields and returns are available to all farmers regardless of size of holding or other characteristics (distributional performance).

In this study, the extent of improvement of the LSVs is examined in Coimbatore, an area well endowed with resources and well developed in terms of agricultural infrastructure. Thus, comparative field performances of paddy varieties are measured in an area where constraints on supplies of irrigation water, credit and other inputs including extension were thought to be at a minimum. Coimbatore farmers have had considerable experience with HYVs, first as EVs, and more recently with LSVs which have gained fast popularity.

The section below describes the analytical framework used to test the main hypothesis, and the major analytical techniques used in the study.

Analytical Framework

The contribution of LSVs towards accelerating the growth of paddy production can be measured by comparing the location and shape of the production curves of LSVs and EVs and analysing the changes. Neo-classical production function analysis enables us to measure the shift in terms of certain characteristics based on economic theory. This measurement is based on the assumption that the shift between the curves is of a Hicks-neutral type.[1]

Farmers cultivating a particular variety under homogeneous production conditions can be expected to obtain more or less equal yields.[2] Significant differences in yields among such farmers cultivating under such conditions could occur either because the assumption of homogeneous production conditions is not correct or because there are some unobserved random errors.[3] Such differences, can be analysed in a number of ways. One approach followed by the International Rice Research Institute (IRRI) in the Philippines is that of identifying the 'yield gap' between the potential yield, which is possible on the farm if the farmers used optimum levels of inputs, and actual yields obtained by the farmer.[4] According

1 Hicks neutral change means the curves differ only by intercept and not by slope. This is statistically tested at a later stage below.

2 By homogeneous production conditions, we mean more or less same climate, weather conditions, drainage and irrigation facilities, soil type and input availability including credit.

3 A statistical verification is attempted in this study.

4 See Constraints to increasing rice production, International Rice Agro-economic Network (IREAN) 1975 General Report, International Rice Research Institute, Los Banos, Philippines.

to their definition, this potential yield is not actually realised by anyone and all actual farm yields differ from it. Thus, this potential yield, from which deviations in yield among farmers are calculated, is a theoretical one. The approach adopted in this study uses a different definition of potential yield, which is realisable. It is assumed here that a farmer who understands the programme thoroughly and translates his knowledge to practice, obtains a yield which is the maximum feasible one under field conditions with the new technology.[5] If a production function, using yield as the dependent variable is defined in the neo-classical sense of expressing the maximum product obtainable from a combination of factors with a given state of technical knowledge,[6] it can be represented as:

$$Y_i = \max \{f_i(X_i, X_2, \ldots X_n)/H_i\} \tag{3.1}$$

in which Y is yield per acre, Xs are per acre levels of inputs and H refers to the state of understanding of the programme, for the i^{th} farmer. A maximum feasible yield (MFY) can be defined from (3.1) with our assumption as follows:[7]

$$y = \max \{Y_i/H_i\}^{8} \tag{3.2}$$

---

5 As discussed earlier in Chapter 1, the location of the study area was found by the PEO-ANU Surveys to have very suitable conditions for the implementation of the HYVP, so this is a fairly realistic assumption.

6 Carlson, S. (1956) A study in the pure theory of production, Kelley and Millman Inc., New York (p.14).

7 This formulation is analogous to the industry production function used by Aigner and Chu. [Aigner, D.J. and Chu, S.F. (1969) 'On estimating the industry production function', American Economic Review, Vol.58 (pp.826-38)].

8 This function is called a 'frontier-production function' in the literature.

Thus, this MFY[9] is realised by at least some of the sample farmers who had understood and closely followed the programme recommendations,[10] and contrary to IRRI's approach, the yield from which the differences in yields among the farmers are calculated is realised and is attempted by all sample participants. This MFY is feasible not only in that some farmers do obtain it but also in that it could be realised by all farmers with existing technology, provided they follow the programme recommendations very closely and have access to the necessary inputs. Equation (3.2) can be estimated by the techniques used by Aigner, Lovell and Schmidt,[11] and Battese and Corra,[12] as discussed in detail in the following section. The difference between the MFY and the actual yield obtained by the farmer can be called the 'Farmer Yield Gap' and the success of the physical performance of the modified HYVP can be measured in terms of this gap. The smaller it is, the more successful is the physical performance.

Identification of the factors inducing the 'Farmer Yield Gap' is a prerequisite for minimising it. If these differences were caused by any unknown random factors, nothing could be done about them. But, if,

---

9 This MFY is of course different from the potential yield available under experimental conditions.

10 It is often argued that recommended practices are framed by agronomists and plant breeders without reference to any economic criteria such as maximisation of net returns. This criticism is most typically heard in relation to fertiliser recommendations, as their costs are high. However, in the present study area, most of the sample participants applied fertilisers at or beyond recommended levels. Other technical recommendations do not involve any or significant additional expenditures, e.g., seed treatment with chemicals before sowing and timing of application of fertilisers and pesticides. It might be expected that these could be accepted even more easily, provided technical reasons were sound.

11 Aigner, D.J. et al. (1977) 'Formulation and estimation of stochastic frontier production function models', Journal of Econometrics, Vol.6 (pp.21-37).

12 Battese, G.E. and G.S. Corra (1977) 'Estimation of a production frontier model: with application to the Zone of Eastern Australia', Australian Journal of Agricultural Economics, Vol.21, No.3 (pp.169-79).

for example, the homogeneity conditions were found to be invalid, then it becomes necessary to find out which of the factors of production contradict the homogeneity assumption. Regression analysis enables us to find out the magnitude of the contribution of these probable factors to the gap. This identification could help the policy makers to create and implement programmes supplementing the HYVP to help the farmers realise the maximum potential of the programme and thereby boost yield and production levels. The monetary performance of LSVs, which is another indicator of their success, is related to the question of which of these varieties (LSVs or EVs) yield more profits per acre within the context of the existing inputs supply system. The distributional performance of LSVs is another component of the success of LSVs measured in terms of the distribution of gains among the cultivators. But, the distributional performance is a mixture of the scope of the opportunities provided by the technology and the capacity and willingness of farmers to take full advantage of them. To work out the impact of LSVs, it becomes necessary to separate the effects on the distribution of benefits of other aspects of technology and the capacity and willingness of farmers. It is possible to evaluate their performances by examining farmers' economic performance which can show whether they do actually avail themselves of the potential performance of LSVs. Comparative economic performance can be measured by comparing the economic efficiencies of sample farmers utilising the technology.

Economic efficiency is an elusive concept in the literature. It is composed of technical efficiency, whereby the greatest output is obtained from any given set of inputs in a technical production function, and price efficiency, which yields equality between the marginal value products and opportunity costs. The following hypothetical example explains the term in detail and the purposes for which it is used in this study.

For a farm producing paddy with a number of factors of production, $X_1, X_2, \ldots X_n$, there are many different combinations of factors that will produce a unit of output. This can be represented by the following function $y = f(X_1, X_2, \ldots X_n)$. Assuming a linearly homogeneous production process, the unit isoquant depicting the combinations of factors that yield one unit of output can be represented by:

$$1 = f^o(X_1, X_2, \ldots X_n) \tag{3.3}$$

It is defined, in the context of the production function (3.1) as representing the minimal combinations of inputs that can produce the unit of output, and so the uniqueness of the isoquant is guaranteed. Let the position of farm A in the input space be represented by the combination of inputs $(X_1^1, X_2^1, \ldots X_n^1)$. If we find that the combination selected by farm A to produce one unit of output, lies on the unit isoquant f^o, then we say farm A is technically efficient. On the other hand, if the combination selected by farm A to yield a unit output lies above unit isoquant f^o, then farm A is said to be technically inefficient.[13] However, the selection of the best input combination from a given isoquant depends on input and output prices. Let the isocost plane which indicates the minimum cost for producing a unit output at relative prices, $p_i (i=1,2,\ldots n)$ is represented by:

$$C^o = g_o(p_1, p_2, \ldots p_n) \tag{3.4}$$

13 The possibility of the combination of inputs selected by farm A lying below the isoquant (3.3) is ruled out because of the existing technology.

Then the concept of price efficiency is explained as follows. With this (Equation 3.4), there are three possibilities for a farm in the selection of the input combination to yield a single unit of output.

a. The combination selected by farm A $(X_1^1, X_2^1, \ldots X_n^1)$ lies on the unit isoquant f^o, but not at the point where the isocost plane C^o is tangential to f^o.

This is the case of farm A showing technical efficiency, but not price efficiency (Figure 3.1).[14]

b. The combination $(X_1^1, X_2^1, \ldots X_n^1)$ does not lie on f^o, but on farm A's isoquant at the point where it is tangential to an isocost plane drawn parallel to C^o, assuming constant prices.

In this case, farm A is said to be price efficient but not technically efficient (Figure 3.2).

c. The combination $(X_1^1, X_2^1, \ldots X_n^1)$ lies at the point of tangency of f^o and C^o.

Then farm A can be declared as being both technical and price efficient and is therefore economically efficient (Figure 3.3). 'Price efficiency and technical efficiency are necessary, and also when occurring jointly, they are sufficient conditions for economic efficiency.'[15] Profit function analysis as introduced by McFadden[16] is used in this study to measure relative economic efficiency of sample farms by identifying their technical and price efficiency components. It is used here to

---

14 For simplicity only two inputs are considered in the hypothetical figures.

15 Yotopoulos, P.A. and J.B. Nugent (1976) Economics of development: empirical investigations, Harper & Row, New York (p.73).

16 McFadden, D.L. (1970) 'Cost, revenue and profit functions', Department of Economics, University of California, Berkeley. (mimeo).

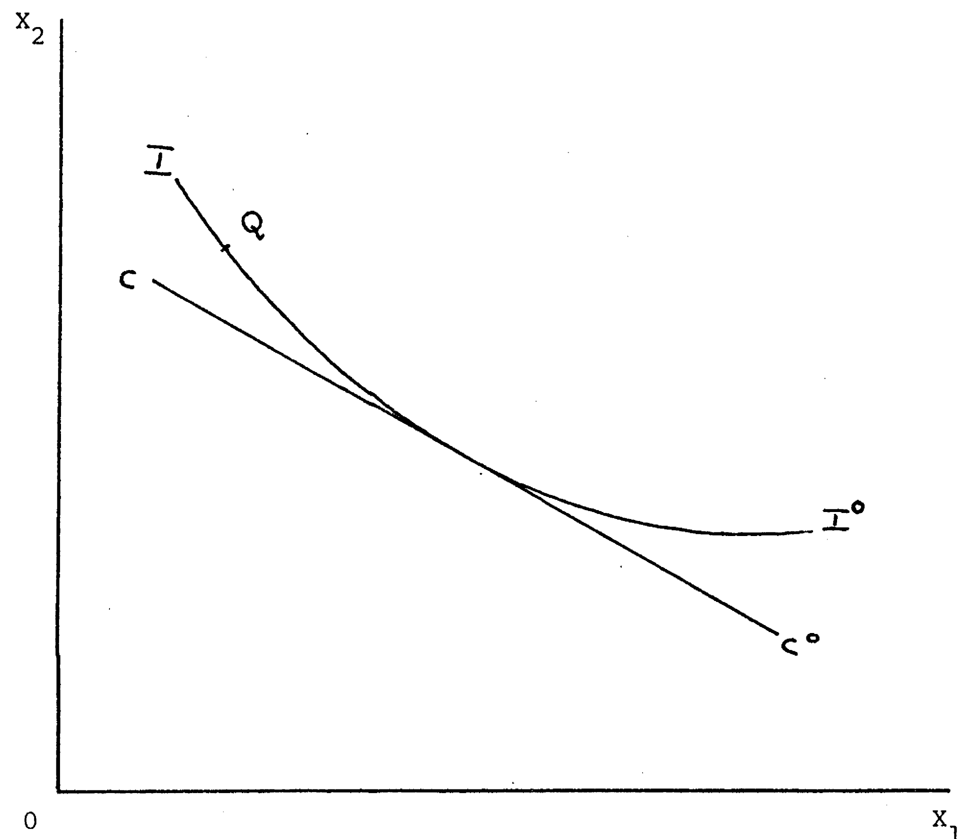


FIGURE 3.1: Technically efficient; price inefficient

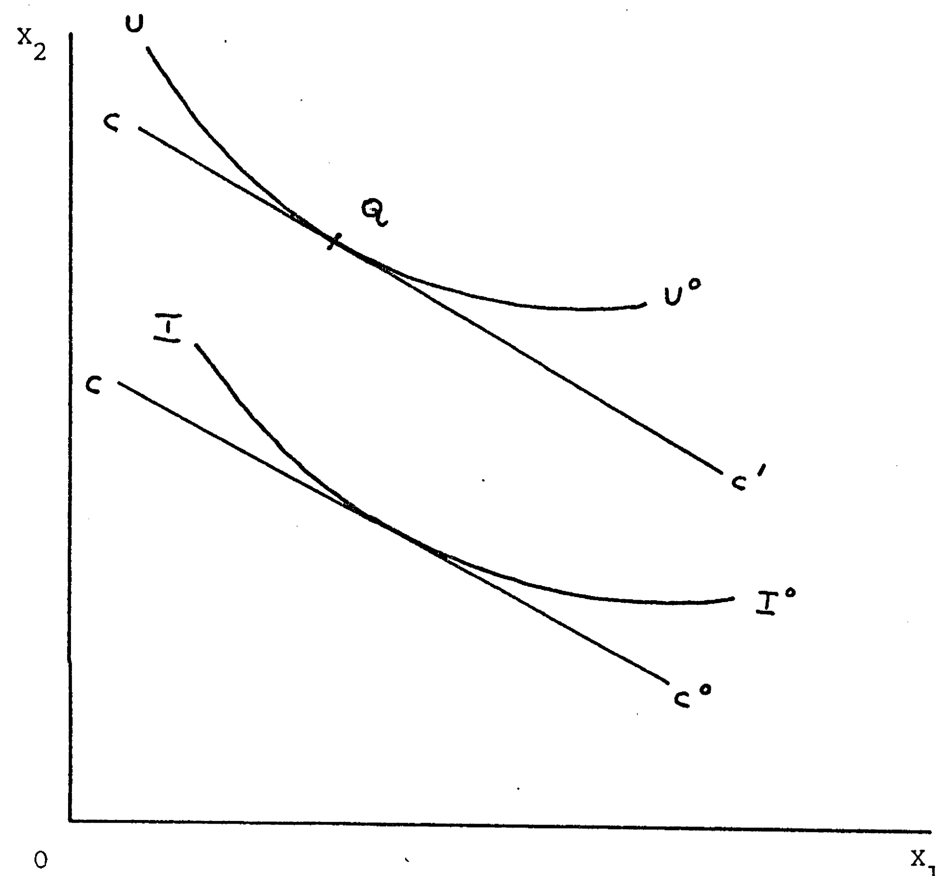


FIGURE 3.2: Price efficient; technically inefficient

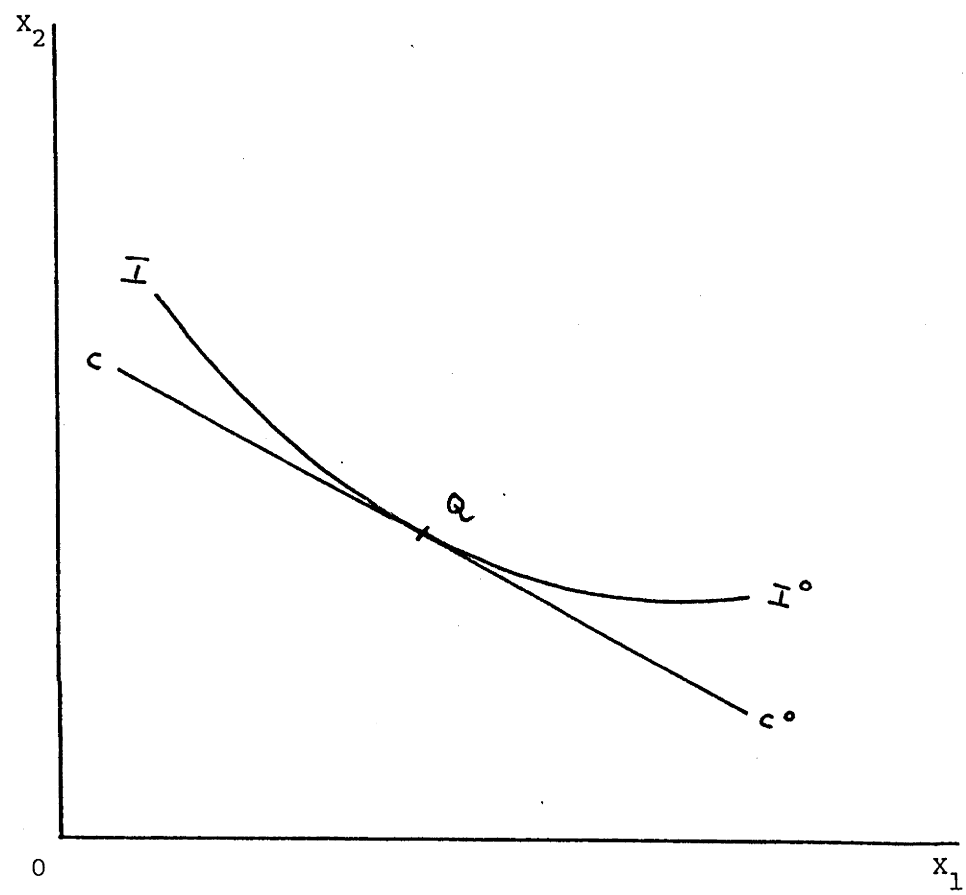


FIGURE 3.3: Economically efficient: Technically and Price Efficient

examine the economic efficiency of farms growing LSVs and EVs. Comparison of these results will indicate whether the introduction of LSVs has brought about any change in economic efficiency over that shown with the use of EVs. This analysis is also used here to compare the economic efficiency of large and small farms, which will provide some insights into the distributional implications of the modified technology.

As discussed earlier, evidence from implementation of the new technology indicates that the gains from the HYVP have been unevenly distributed with large and medium farmers profiting most from it.[17] A further part of the analysis is therefore to calculate distribution of residual farm income from the new technology amongst sample farmers.[18] Residual income distribution from HYV paddy farming in the study area is first examined in relation to the distribution of land ownership by size of holdings. Second, the impact of the HYVP is then examined using the distribution of input use according to the same farm size distribution. Third, the distribution of income from HYV paddy farming is estimated and compared with the base distribution of land ownership and input use to observe whether changes have taken place as a result of the adoption of HYVs (LSVs and EVs) and of input use, i.e., whether adoption of the new technology has improved or worsened the distribution of income arising from the pattern of land ownership. Further, comparison of the distribution of income from LSVs and EVs use allows judgement as to the distributional effects for farmers of switching from EVs to LSVs.

---

17 Frankel, F.R. (1969) 'India's New Strategy of Agricultural Development', Journal of Asian Studies, Vol.28, No.4 (pp.693-710).

Byres, T. (1972) 'Dialectics of Green Revolution', South Asia Review, Vol.5, No.2 (pp.99-116).

18 It is assumed that this is what farmers want to maximise. See Shand, R.T. (1978). Throughout this study income means farm residual income only.

These comparisons are made using the Lorenz curve, and the degree of inequality is measured by the Gini concentration indexes based on these Lorenz curves.

Analytical Techniques

Production Function Analysis:

Production function analysis is useful for deriving measurements of relations between input use and yields at farm level. It also enables analysis of the impact of different technologies through measurement of shifts in production functions and changes in factor intensities. It is based on the assumptions that:

a. The farmers are observed in a range of circumstances at one time, e.g., with different sizes of operational holdings and levels of input applications.

b. Farmers are price takers in both product and factor markets and factor prices are fixed competitively.[19]

c. All farmers maximise profit based on anticipated output (yield) and so the production process can be explained by a single equation model.[20]

d. Within the study area, all farmers have access to the same information on the technology of the HYVP.

---

19 As already mentioned, fertiliser and pesticide prices are fixed by the Government and vary only slightly according to geographical locations. Wage levels are very much determined competitively in the village market at least locally. The form and amount of payment for leased-in lands is also determined in the market. Competition in factor markets implies that the level of supply curves for these factors can differ among farms, but not the slope of the curves.

20 'It is likely that, if the purpose of the model is to predict output for given quantities of input, the single equation approach will be best' Walters, A.A. (1963), 'Production and cost functions', Econometrica, Vol.31, Nos.1-2, (pp.1-66), (p.17).

Economic Specification: Minimising the degree of multicollinearity is an important consideration in selection of variables for the production function. Omission of any relevant variable will bias the estimate of production coefficients, and while the inclusion of an irrelevant variable will not bias the estimate, it will reduce the degrees of freedom and increase the possibility of multicollinearity and autocorrelated residuals.[21] Thus, the process of selection for the production function can lead to two kinds of bias, namely, specification and management biases. Specification bias has been taken into account in the third assumption above for the production function, which states that the farmer's input applications depend on his anticipated output.

Quite a number of approaches have been suggested for inclusion of management in the production function. These can be classified in three broad categories. First, observations can be divided into different groups of managerial levels based on some *a priori* reasons, and then production functions can be estimated separately for these groups.[22] The difficulty with this approach is the selection of an *a priori* reason. Also, 'if the condition of uniform managerial capacity among farms exists, fixity of resources as a result of managerial activity, the ability of more efficient managers to use superior production functions, and correlations between managerial capacity and resource categories, do not

---

21 Heady, E.O. and J.L. Dillon (1961) *Agricultural production functions*, Iowa State University Press, Ames, Iowa.

22 Massell, B.F. (1967) 'Farm management in peasant agriculture: an empirical study', *Food Research Institute Studies*, Vol.VII, No.2 (pp.205-15).

permit study of resource productivity in producing managerial services'.[23]

In the second category, the effect of management on output has been studied by explicitly introducing a management index in the production function. This can be either a weighted score based on descriptive assessments of good and poor management performance, or a single proxy variable, or combination of these like education of the farmer.[24] The main shortcoming of this approach is the unrealistic assumption of independence between the management index and other factors of production. Further, 'though a decision to use different input levels or different cultural practices does change output indirectly, it is the inputs or practices, not the decision, which is a factor of production. Since the decision changes output indirectly, its relation to production should also be examined indirectly'.[25]

Mundlak and Hoch, the proponents of the third category, introduced management to production functions through variance and co-variance analysis by combining observations from both time series and cross-section data.[26]

---

23 Johnson, G.L. (1956) 'Problems in studying resource productivity and size of business arising from managerial processes' in E.O. Heady et al. (eds.), Resource Productivity, Returns to Scale and Farm Size, The Iowa State College Press, Ames, Iowa (p.20).

24 Griliches, Z. (1964) 'Research expenditures, education and the aggregate agricultural production function', American Economic Review, Vol.54 (pp.961-74).

Chaudhri, D.P. (1974) 'Effect of farmer's education on agricultural productivity and employment - a case study of Punjab and Haryana States of India (1960-72)', Faculty of Economic Studies, University of New England, Armidale (mimeo).

25 Johnson, G.L. (1967) 'A note on non-conventional inputs and conventional production functions', in C. Eicher and L. Witt (eds.), Agriculture in Economic Development, McGraw-Hill, New York (p.120).

26 Mundlak, Y. (1961) 'Empirical production function free of management bias', Journal of Farm Economics, Vol.XLIII, No.1 (pp.44-56).

Hoch, I. (1962) 'Estimation of production function parameters combining time-series and cross-section data', Econometrica, Vol.30, No.1 (pp.34-53

Massell extended this technique to a cross-section of multi-product farms for a single time period.[27] The effect of management on production could be considered either as a neutral multiplicative factor affecting only the intercept, or as a fully multiplicative factor affecting both the intercept and slope.[28] In the former case, good management shifts the production function neutrally from the production function of the farmers with poor management, and in the latter case, the good management production function not only changes location, but also shape from the poor management production function. The solution in the latter case, through an iterative procedure is tedious and has to be continued until some predetermined set of criteria are fulfilled. Also it consumes a considerable number of degrees of freedom. Further, the statistical properties of the model are not easy to understand because the individual estimates of multiplicative management effect and any trial yield coefficients in the model may not be consistent from one iteration to the other. Apart from these difficulties, our study does not satisfy the data requirement for this approach of an equal number of observations from the same farms over a period of time.

Risks in agriculture can broadly be divided into yield and price risks. Usually, 'price risks for both inputs and outputs are ignored for two reasons: (i) price risk is generally small in comparison to yield risk; and (ii) even when there is considerable variation of rice prices as there has been since the introduction of HYVs in 1966, the high covariance between the prices of different rice varieties, owing to a high elasticity of substitution on the demand side, reduces the role of price variability in choice of technique'.[29] In this study, Coimbatore is a deficit district for foodgrains owing to a fairly heavy concentration of

27 Massell, B.F. (1967) 'Elimination of management bias from production functions fitted to cross-section data: a model and an application to African agriculture', Econometrica, Vol35, Nos. 3&4, (pp.495-508).

28 Etherington, D.M. (1973) An econometric analysis of smallholder tea production in Kenya, East African Literature Bureau, Nairobi.

29 Roumasset, J.A. (1975) Rice and Risk, North-Holland Publishing Co., Amsterdam (p.53).

secondary industries and a high proportion of urban population, and consequently paddy prices are consistently at levels attractive to producers. Further, Coimbatore district borders on neighbouring Kerala State, where foodgrains production is at even lower levels and deficits are greater. High prices lead to illegal smuggling of rice by traders into Kerala from Coimbatore, which results in a greater deficit in the latter and to a strengthening of prices.

Yield risks arise from monsoon weakness or failure, from other climatic conditions and from pest and diseases damage. Yield risk from monsoon and other weather conditions has not been evident during the last decade in the study area as that part of the district received assured surface irrigation by canals and channels from dams across the river Cauveri and its tributaries. The paddy crop was subject to attack by the Brown Plant Hopper (BPH), but field data in this study indicated that farmers took preventive and/or curative measures. It is often argued that risks are generally perceived by farmers as being more formidable in new technologies and consequently they tend to act as an impediment to the adoption of improved practices.[30] Data presented below for this study show contrary evidence, that almost all sample participants applied the recommended doses of fertilisers and pesticides or levels in excess of these and that these attacks were no hindrance to adoption. The above reasons would suggest that production and price risks in this district are in fact unusually low and for that reason it is not attempted to study risk in this analysis.

---

30 Anderson, J.R. (1974) 'Risk efficiency in the interpretation of agricultural production research', Review of Marketing and Agricultural Economics, Vol.42, No.3, (pp.131-84).

Selection of Variables: With these assumptions, the production function adopted for the analysis:

$$y = f(X_1, X_2, X_3, X_4) \tag{3.8}$$

where y represents yield measured in tons per acre of cultivated land. Productivity of this land is the product of both irrigation facilities and soil type.[31] All sample farms were canal irrigated which encouraged paddy to be cultivated exclusively, within the command area and the whole area came under the single category of red loamy soil.[32] Hence, it could be reasonably assumed that productivity variations among sample farms were very minimal.

Labour input (X_1) is measured in man-days (eight hours). It is assumed that labour is homogeneous. Labour is not, of course, homogeneous, but allowance for this can be made if the variable included in the production function reflects these quality differences, difficult though this is. In practice, hired labour varied by type (male, female and child) and problems arise in aggregating them. It has been suggested that 'weighting the different types of labour by a base year's marginal products is an appropriate method',[33] and that the marginal products be estimated by wages. In the study area, though it was observed that both the male and female

31 Here it may be necessary to differentiate between soil fertility and productivity. The former refers to soil nutrient status, both total and available nutrients present in the soil, whereas the latter refers to soil's yield capacity.

32 Government of Tamil Nadu (1974) Soil Survey of Gobichettipalayam, Report No.17, Soil Survey and Land Use Organisation, Coimbatore (p.33). The soil series of Seyyampalayam has been named the Irugur series. Usually, series are named after the place where a particular type of soil is first found. The characteristics of Irugur series are - red colour, moderately deep and loamy neutral PH.

33 Walters, A.A. (1968) An Introduction to Econometrics, McMillan, London (p.324).

hired labourers did the same kind of work in almost the same time, the male was paid at a higher rate. Given the apparent equality in contribution, they were not differentiated in the present study. However, the day's work done by a child of 14 years or less was considered as one half of a man-day. It is interesting to note that in this study area, family labour was employed only in a supervisory capacity. So, first the total number of hours spent in the field by family members were calculated irrespective of sex, and were converted to labour man-days.[34] Second, since family labour was used only for management decisions and for farm supervision, these inputs were incorporated in the production function as a variable showing the managerial ability of the family labour. This was done by weighting the family labour man-days by a factor described below to account for the managerial ability of the family labour.

It is assumed that farmer's managerial ability mainly depends on his knowledge about the recommendations of different field activities of the HYVP. Though there were a number of educated members in each farm household in the study area, the management decisions finally were taken by the head of the family. Therefore, only the head of the farm household was asked about the different recommendations of the HYVP and answers that were close to official recommendations each were given a score of unity which means farmer's supervision (managerial ability) in respect to that particular recommendation has contributed to yield. Answers that were not close to recommendations were given a score of zero which implies that farmer's supervision (managerial ability) in respect to that particular recommendation has not contributed to yield. Total family labour man-days of each farm was then weighted by the ratio of its

---

34 The data showed no child family labour was used on the sample farms.

achieved scores to the total possible. This enabled the introduction of managerial ability of the family labour in the production function indirectly.

X_1 in equation (3.8) is thus calculated as the sum of hired[34a] and weighted family labour in man -days per acre.

Fertiliser inputs (X_2) could incorporate both organic manure and chemical fertilisers. Sample participants did use organic manures, but analysis by the Fertiliser Inspector in the Office of the District of Agricultural Officer, Gobichettipalayam has shown that they do not contain any significant nitrogen (N), phosphorous (P) or potassium (K) nutrients, as they are not prepared properly. Therefore, green manures were not included in the function. Further, sample farmers typically used their own household and animal wastes, for which operating costs were low. This farmyard manure is also not prepared properly. For example, it is recommended by the Fertiliser Inspector that the ditch in which the farmers collect the farmyard manure be closed for at least a month before the manure is used. This requires another ditch to throw a month's waste. In the study area farmers used only one ditch and so the farmyard manure was not prepared as recommended. Hence, in the present study only chemical fertilisers were included in the production function. X_2 in equation (3.8) denotes total expenditure (Rs.) per acre on fertilisation, and is the sum of expenditures on fertilisers and total wages paid for thie application by hired labour.[34b] This means that the average prices for fertilisers are similar for all sample participants. This can be valid because the prices of fertilisers are fixed by the

---

34a Hired labour used for harvesting, threshing and bundling is not included as it does not affect yield. Labour used for applying fertiliser is combined with variable X_2 defined below.

34b If fertiliser is represented in quantity equivalent of total nutrients in the production function, the marginal productivity of this factor wil be the sum of marginal productivities of nutrients and labourers who applied it. Thus, the marginal productivity of nutrients alone cannot be separated out.

government. However, there can be a marginal variation in prices depending on the distance between the farms and shops.

X_3 in equation (3.8) represents rupee expenditures per acre on other inputs which include seeds, bullocks, tractors and mechanical sprayers hired, and interest charged on loans for these inputs, if any. Aggregation over these different inputs implies causing a bias in the estimated parameters of the production function (3.8). To minimise specification bias due to aggregation, Plaxico suggested a working rule that perfect complements used in fixed proportions should be treated as a single input and perfect substitutes should also be aggregated into a single input.[35] If inputs do not come under these categories, then aggregation can also be justified on the following facts: (i) taken individually, each of inputs has only a small influence on yield, and (ii) would reduce the degrees of freedom available for statistical tests of parameters, if treated each of inputs separately.[36]

Capital has been classified in a number of ways in production function analysis. Heady and Dillon have given a detailed historical sequence of the classification of capital used by different researchers. The most usual classification of capital are as fixed, circulating and working capital, the most appropriate of which is the magnitude of service flows from fixed and stock capital.[37] Capital flow can be defined as the sum of depreciation, maintenance and opportunity costs of capital stock. Depreciation is calculated by the straight line method and opportunity costs are derived by multiplying the stock by 12 per cent which is the lending rate of the local co-operative societies.

Thus, X_4 in equation (3.8) represents capital flow per acre used in the production of paddy.

35. Plaxico, J.S. (1955) 'Problems of factor-product aggregation in Cobb-Douglas value productivity analysis', Journal of Farm Economics, Vol.37, No.4, (pp.664-75.

36 Desai, B.M. (1973) "Economics of resource use on sample farms of Centra Gujarat', Indian Journal of Agricultural Economics, Vol.28, No.1, (pp.71-86).

37 Klein, L.R. (1962) An introduction to econometrics, Prentice-Hall Inc., Englewood, Cliffs.

<u>Functional Specification</u>: Numerous alternative mathematical forms can be used as production functions. The shape of a production curve, according to production theory, depends on the nature of complementarity and substitutability among the factors of production. There are three possible cases.[38]

a. Complementary factors of production with fixed proportions.

b. Complementary factors of production with variable proportions.

c. Full substitutability between factors of production.[39]

In agriculture, the possibility of inputs being either of type b. or c. is high. To each of these latter two types of inputs, two types of production functions can be associated - Transcendental and Cobb-Douglas respectively, of which, the transcendental function incorporates all the three stages of production,[40] while the Cobb-Douglas explains only the important second stage of production assuming perfect competition.

These two functions need all the inputs to form an output. This restriction could be overcome by fitting a quadratic type of production function. Besides these, a translog type of production function was also attempted. Since, it is very difficult to work with CES function for more than two inputs, it was not attempted.

---

38 Ott, A.E. (1962) 'Production functions, technical progress and economic growth', <u>International Economic Papers</u>, No.11, (pp.102-40).

39 Full substitutability is different from perfect substitutability which means two factors of production are identical. In that case, the isoquant is a straight line with gradient -1.

40 Halter, A.N. et al. (1957) 'A note on the transcendental production function', <u>Journal of Farm Economics</u>, Vol.39, No.4, (pp.966-74).

The following production functions were given preliminary trial in this study:

a. Cobb-Douglas $Y = \alpha \prod_{i=1}^{n} X_i^{\beta_i}$

b. Transcendental $Y = \alpha \prod_{i=1}^{n} X_i^{\beta_i} e^{\sum_{i=1}^{n} \gamma_i X_i}$

c. Quadratic $Y = \alpha + \sum_{i=1}^{n} \beta_i X_i + \sum_{i \neq j} \gamma_i X_i X_j - \sum_{i=1}^{n} \sigma_i X_i^2$

d. Translog $\ln Y = \alpha_o + \sum_{i=1}^{n} \alpha_i \ln X_i + \frac{1}{2} \sum_{i=1}^{n} \sum_{j=1}^{n} \gamma_{ij} \ln X_i \ln X_j$

where Y represents yield and X_i inputs per acre.

Of these four forms of production curves, the Cobb-Douglas form was chosen for further analysis in this study on the basis of adjusted R^2 for degrees of freedom and the maximum number of significant estimates of the production parameters.[41] Hayami and Ruttan, with intercountry comparisons of productivity conditions, concluded that the unitary elasticity of substitution, characterizing the Cobb-Douglas production function, fitted their cross-sectional data very well.[42] Lau and Yotopoulos, Desai and Sidhu and many others have found the Cobb-Douglas gives the best fit amongst the forms tried using Indian data.[43]

41 It is also relatively easy to interpret the parameters. The estimated functional parameters are presented in Appendix 3.3 to 3.6.

42 Hayami, Y. and V.W. Ruttan (1971) (p.104).

43 Yotopoulos, P.A. et al. (1970) 'Labour intensity and relative efficiency in Indian agriculture', Food Research Institute Studies, Vol.9 (pp.43-5).

Desai, B.M. (1973) 'Economics of resource use on sample farms of Central Gujarat', Indian Journal of Agricultural Economics, Vol.28, No.1 (pp.71-85).

Sidhu, S.S. (1972) 'Economics of technical change in wheat production in Punjab, India', unpublished doctoral dissertation, University of Minnesota.

Statistical Specification and Estimation: It is always assumed in estimating production functions empirically, that discrepancies exist between estimated and actual values. These are referred to as 'disturbance' in theory of estimation. 'In any empirical application we must of course specify...the properties of the random disturbance terms that must be added to allow for the effect of all variables ignored in the analysis'.[44] The disturbance terms may represent either the net effect of the variables not included in the equation (they might be certain aspects of management, or solar radiation for example, in the present study), or errors of observation and measurement, or there may be a basic and unpredictable element of randomness (weather). The assumptions about the structure and distribution of disturbance terms determine the kind of production function (whether MFY or some kind of average yield) estimated by the identity,

$$y = f(x) + u \tag{3.9}$$

a. If the following assumptions about u are made, then f(x) will represent an average production function (the most frequently estimated function in production economics), reflecting some sort of average technology.

(i) The expected value of u on each occasion is equal to zero i.e., $E(u_i) = 0$

(ii) u is independent of time so that there is no serial correlation among disturbances

i.e., $\underset{i \neq j}{E} (u_i u_j) = 0$

but $\underset{i=j}{E} (u_i u_j) = \sigma^2$

---

44 Cramer, J.S. (1969) Empirical Econometrics, North Holland Publishing Company, London (p.199).

(iii) If x_i's are considered as random variables, then they have independent joint distribution with u i.e., $E(x_i u_i) = 0$

(iv) u is distributed normally as $N(0,\sigma^2)$

With these assumptions, the method of least squares, (usually called OLS) which consists of minimising the sum of squares of the disturbances between the observed and estimated values, can be used to estimate the production parameters.

Representing the logarithms in small case letters, (3.9) can be rewritten in matrix notation,

$$y = x\hat{\beta}+u \tag{3.10}$$

where y is (nxl) column vector, x is a matrix of fixed number of order (nxk) with rank kxn, β is a column vector of order (kxl), u is (nxl) column vector of disturbance with $E(u) = 0$, and $E(uu') = \sigma^2 In$.

Let $\hat{\beta}$ denote a column vector of estimates of β. Now we can write,

$$y = x\hat{\beta}+e \tag{3.11}$$

where e is the column vector of n residuals $(y-x\hat{\beta})$.

Now the method of least squares requires that the sum of squares of the residuals between the fitted and observed be a minimum.

$$\begin{aligned} \Sigma e_i^2 &= e'e = (y-x\hat{\beta})'(y-x\hat{\beta}) \\ &= (y'y-y'x\hat{\beta} - \hat{\beta}'x'y + \hat{\beta}'x'x\hat{\beta}) \end{aligned} \tag{3.12}$$

Partially differentiating (3.12) with respect to $\hat{\beta}$'s and equating to zero, $\hat{\beta}$'s are obtained.

$$\frac{\partial e'e}{\partial \hat{\beta}} = -2x'y + 2x'x\hat{\beta} \quad (\because \hat{\beta}'x'y \text{ is a scalar and is thus equal to its transpose } y'x\hat{\beta}).$$

$$= 0 \tag{3.13}$$

therefore, $\hat{\beta} = (x'x)^{-1}x'y$ (3.14)

'In this model it is generally assumed that such differences between actual and estimated are not very important and are distributed randomly across firms. This kind of analysis does not deny the importance of these productivity differences, but offers little to explain these differences.'[45]

The estimated function will be an average production function. This function is used in this study: (i) to measure the shift in the production function; and (ii) to describe the nature of average technology of the HYVP present in the study area.

b. The maximum feasible yield concept defined in (3.2) is the production function underlying what may be considered as the best practice techniques among a given group of producers. Hence, it is not necessarily the same as the production function of the experimental results obtained by highly qualified scientists in the research stations. With the level of technology known to sample participant farmers, our interest is to find out the highest yield obtained using the best practice technique at field level. The production function showing such yield[46] may be estimated empirically in a number of ways.

With one input and one output, the estimation of MFY becomes easy. First, with the assumption of constant returns to scale, the ratio of

45 Muller, J. (1972) 'The impact of information on technical efficiency', Stanford University Ph.D. Thesis, Xerox, (p.6).

46 This is called 'frontier production function' in the literature.

output to input may be calculated for a number of farmers and the highest of all would then represent MFY. Second, if the assumption of constant returns to scale is not made, then input and output of the farmers may be plotted on a scatter diagram. Specifying a functional form for the relationship between input and output, a smooth curve can be drawn through the highest of these points and this would represent the MFY function.

With two inputs and one output represented by:

$$y = f(X_1, X_2) \tag{3.15}$$

the MFY can be estimated as follows: First, assuming constant returns to scale, the ratio of each input to output $(X_1/y, X_2/y)$ may be plotted in a scatter diagram (Figure 3.4). Each point in the scatter diagram represents the combination of inputs X_1 and X_2 used to produce a unit of output y. A line joining the lowest of these points would be the MFY function (AA'). Second, without the assumption of constant returns to scale, specifying a functional form for (3.15), a smooth curve may be drawn through the lowest of the points in scatter diagrams which would represent the MFY function. The former approach was used by Farrell[47] to measure the technical inefficiency of farms in relation to the function thus estimated. The major criticism of this approach is that it uses only marginal observations and a vast bulk of data does not enter the estimation procedure. But, it is possible to fit a smooth curve showing MFY, using all observations in the estimation.

Extending the above model of two inputs and one output into one output and n-inputs and specifying a functional form, say, Cobb-Douglas,

---

47 Farrell, M.J. (1957) 'The measurement of productive efficiency', Journal of Royal Statistical Society, Series A (General), Vol.120, Part 3, (pp.253-381).

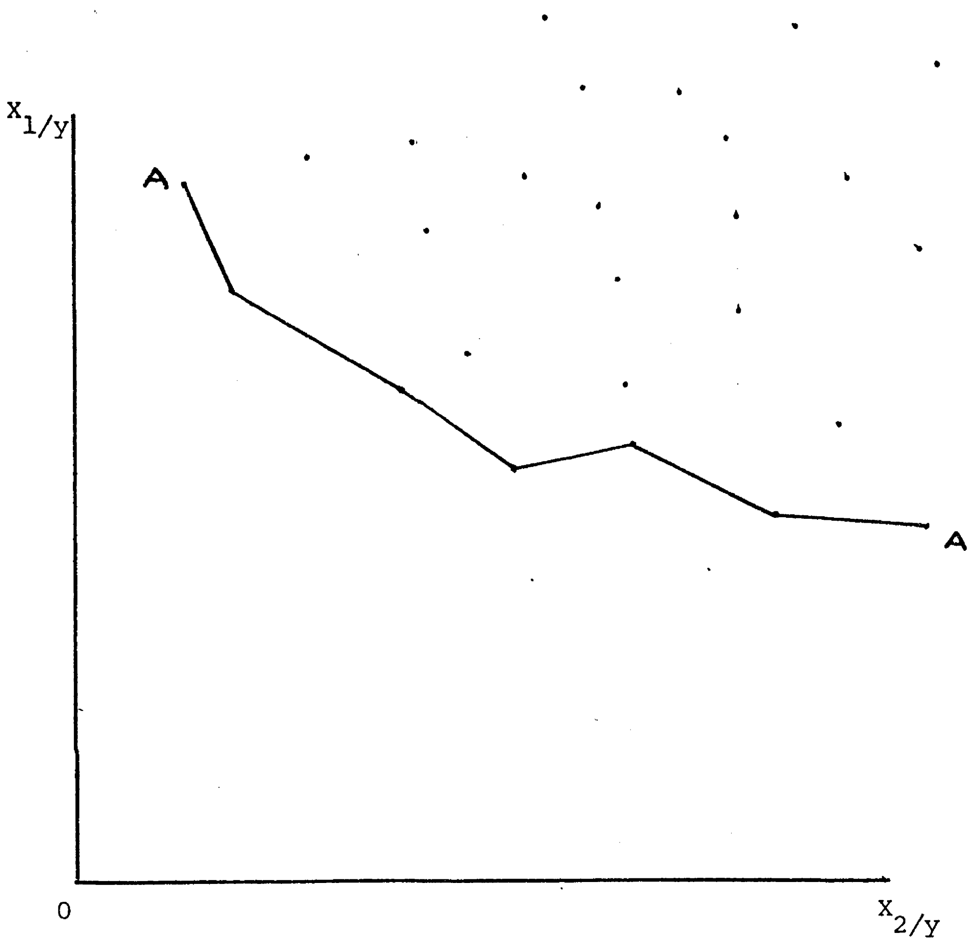


FIGURE 3.4: Maximum feasible yield curve (hypothetical)

we may write the production relationship as:

$$Y = A.\ X_1^{\beta_1} X_2^{\beta_2}, \ldots X_n^{\beta_n} \tag{3.16}$$

Taking logarithms on both sides, and representing the values of logarithms in small case letters, we get,

$$y = a + \sum_{i=1}^{n} \beta_i x_i \tag{3.17}$$

Assuming that the MFY is given by $a + \sum_{i}^{n} \beta_i x_i$ in (3.17), we may say that each farm's output (yield) may be represented by the following relation,

$$y = a + \sum_{i=1}^{n} \beta_i x_i + u \tag{3.18}$$

where u is the difference between the yield obtained (y) by each farmer and yield estimated by fitting the function $(a + \sum_{i=1}^{n} \beta_i x_i)$ to represent MFY on the assumption that u can be either negative or zero. If the farm uses best practice technique, then according to our definition, it will obtain MFY and so u is zero. On the other hand, u will be negative for the farms not using best practice technique and the negative value of u will vary among the farms depending on their technical efficiency according to how close they are to best practice technique, i.e., u negative means that the farm is unable to use or is not using the best practice technique, and yield is less than would be obtained if it used the best practice technique. Even without specifying any probability distribution function for u, a function showing MFY may be estimated by linear or quadratic programming techniques. These programming techniques minimize the sum of absolute differences or the sum of squared differences respectively, under the constraint that all differences be either negative or zero. Aigner and Chu used this method, assuming a Cobb-Douglas function in input-output space.[48]

However, such a programming solution does not take account of the sort of statistical errors, e.g. errors of measurement, which are considered in the usual least-squares methods of regression. This was pointed out by Timmer[49], who provided a simple method of dealing with these errors to some extent. He deleted a percentage of observations (3%), assuming they were affected by statistical errors, and estimated the frontier production function using the remaining observations by a linear programming technique. Thus, he gave a probabilistic approach to the deterministic frontier used by Aigner and Chu. But, the selection of the percentage (3%) was purely arbitrary, lacking economic or statistical justification.

Recently, another approach has been developed which takes account of such statistical errors explicitly in the estimation of the MFY function (frontier production function) as follows:

$$y = a + \sum_{i=1}^{n} \beta_i x_i + u + v \qquad (3.19)$$

where u is the difference between the farm's practice and the best practice technique and u is either zero or negative; v is the statistical error and other random factors such as topography, weather etc., and v is either positive, negative or zero. The above equation (3.19) means that a farm's MFY is defined by $a + \sum_{i=1}^{n} \beta_i x_i$, provided it uses the best practice technique ($u = o$) and there are no statistical errors and the influence of external

48 Aigner, D.J. and S.F. Chu (1968).

49 Timmer, C.P. (1971) 'Using a probabilistic frontier production function to measure technical efficiency', Journal of Political Economy, Vol.79, No.4, (pp.776-94).

factors like climate on production is negligible (v = o). If the farm uses the best practice technique, but there are either statistical errors such as measurement errors or influence of external factors, then the farm's MFY is calculated as $a + \sum_{i=1}^{n} \beta_i x_i + v$.[50] The presence of v, here, also means that the MFY is stochastic with random disturbance v, implying that the MFY function may vary randomly across farms or over time for the same farm. On the other hand, if there are no statistical errors and no influence of external factors on production, then the farm yield obtained will be equal to or less than MFY, depending on whether it uses the best practice technique or not, i.e., whether u is zero or negative respectively.

Given density functions for u and v, the MFY function defined in (3.19) may be estimated by the maximum likelihood technique. One advantage of estimating the MFY function defined in (3.19) with the assumption of density function for u and v, is that it is possible to find out whether the farm's deviation of yield from its MFY is mainly because it did not use the best practice technique or is due to external random factors. Thus, one can say whether the difference between the actual yield obtained and the MFY, if any, occurred accidentally or not.

With the assumption in (3.19) that u is non-positive, a number of density functions can be specified for u. Aigner, Lovell and Schmidt[51] used the above approach assuming a truncated normal (half-normal) distribution for u and a normal distribution for v. They also assumed an exponential distribution for u, along with the normal distribution for v.

---

50 This is called a 'pseudo-frontier production function' by Battese and Corra. [Battese, G.E. and G.S. Corra (1977)].

51 Aigner, D.J., Lovell, C.A.K. and P. Schmidt (1977).

Empirical MFY Function: Assuming the economic and statistical specifications mentioned in equation (3.19), the MFY function which is estimated empirically in this study for kharif season is given as,[51]

$$y = \sum_{i=o}^{7} x_i \beta_i + u + v \qquad (3.20)$$

where y is the logarithm of yield actually obtained; x_o is equal to 1 and x_4, x_5, x_6, x_7 are logarithms of inputs used in the production of paddy; x_1 represents the varietal dummy taking values 1 for location specific high yielding varieties and o for exotic high yielding varieties; x_2 represents the brown plant hopper control dummy taking values 1 for farms not severely attacked and o otherwise; x_3 represents the differential of x_2; u is a random variable showing the difference between the farm's actual practice and the best practice used in the study area, and v is a random variable showing statistical errors like errors in measurement, observation etc. and influence of external factors such as topography, climate etc. β_i's are parameters estimated where β_o represents the intercept term in equation (3.20). Further, u is assumed to be non-positive and has truncated normal distribution, and v is $N(0,\sigma_v^2)$.[52]

Given these density functions of truncated normal and normal distribution for u_i and v_i respectively, the density function of y_i[53] may

---

51 In matrix notation, equation (3.20) may be written as:

$$y = x\beta + \varepsilon \quad \text{where} \quad \varepsilon = u + v \qquad (3.21)$$

52 The density function of u_i is:

$$f_u(u_i) = \frac{1}{\sigma_u\sqrt{\pi/2}} \cdot e^{-\frac{1}{2}\frac{u_i^2}{\sigma_u^2}}, \quad \text{if } u_i \leq 0$$

$$= 0 \text{ , otherwise.}$$

53 The density function of ε_i which is $u_i + v_i$ are derived, along with the density function of y_i in Appendix 3.1.

be defined as,

$$f_Y(y_i) = \frac{1}{\sigma\sqrt{\pi/2}} \{1-F[(\frac{y_i-x_i\beta}{\sigma}) \sqrt{(\frac{\gamma}{1-\gamma})}]\} e^{-\frac{1}{2}(\frac{y_i-x_i\beta}{\sigma^2})^2} \tag{3.22}$$

$$-\infty < y_i < \infty$$

where $\sigma^2 = \sigma_u^2 + \sigma_v^2$ and $\gamma = \frac{\sigma_u^2}{\sigma^2}$.[54] γ is an indicator of relative variability of u_i and v_i that differentiates the actual yield obtained from the MFY. There are two interesting points about γ:

a. When σ_v^2 is tending to zero, which implies that u_i is the predominant error in (3.19), then $\gamma = 1$. This means that the farm's yield differs from the MFY mainly because it did not use the best practice technique.

b. When σ_u^2[55] is tending to zero, which implies that the symmetric error v_i is the predominant error in (3.19), γ is tending to zero. This means that the farm's yield differs from MFY mainly because of either statistical errors or external factors not under its control.

The likelihood function which is the probability density of obtaining the sample $(y_1, y_2, \ldots y_n)$ may be written from (3.22) as,

---

54 This parametrisation γ in the density function of y_i is used by Battese and Corra which differs from λ used by Aigner and others. The advantage of using γ is that it varies between 0 and 1, while λ varies from 0 to ∞. So the complete range of parameter λ from 0 to ∞ should be explored to find the true MFY function. But, with γ the trials are limited between 0 and 1.

55 It may be noted, here, that the variance of u_i is not exactly equal to σ_u^2, but equal to $\sigma_u^2 (\frac{\pi-2}{\pi})$. This is shown in Appendix 3.1.

$$L^*(y;\theta) = \prod_{i=1}^{n} \{\frac{1}{\sigma\sqrt{\pi/2}} [1-F(\frac{y_i - x_i\beta}{\sigma})\sqrt{\frac{\gamma}{1-\gamma}}] e^{-\frac{1}{2}(\frac{y_i x_i \beta}{\sigma^2})^2}\} \tag{3.23}$$

where θ is the parameter to be estimated and is equal to $(\beta'\sigma^2\gamma)'$.

The method of maximum likelihood aims to find an estimate of θ which maximises the value of the likelihood function (3.23). This means that the probability of the sample drawn is large.[56] Since the natural logarithm of a function has the maximum point at the same position as the original function, we take the logarithm of the likelihood function L^*.

$$L(y;\theta) = -\frac{n}{2}\ln\frac{\pi}{2} - \frac{n}{2}\ln\sigma^2 + \Sigma\ln[1-F(W_i)] - \frac{1}{2}[\frac{1-\gamma}{\gamma}]\Sigma W_i^2 \tag{3.24}$$

where $W_i \quad = (y_i - x_i\beta)[(\frac{\gamma}{1-\gamma})\frac{1}{\sigma^2}]^{1/2}$

The ML estimators of θ, maximizing the above likelihood function (3.24) are obtained by setting its first order partial derivatives with respect to the elements of θ, namely, β, σ^2 and γ, equal to zero, i.e., $\frac{\partial L}{\partial\beta} = 0$; $\frac{\partial L}{\partial\sigma^2} = 0$ and $\frac{\partial L}{\partial\gamma} = 0$ and solving them simultaneously.

Now, $$\frac{\partial L}{\partial\beta} = -\sum_{i=1}^{n} \frac{1}{1-F(W_i)} \frac{\partial F(W_i)}{\partial W_i} \frac{\partial W_i}{\partial\beta} - \frac{1}{2}(\frac{1-\gamma}{\gamma})\, 2\sum_{i=1}^{n} W_i \frac{\partial W_i}{\partial\beta} = 0 \tag{3.25}$$

where $W_i = (y_i - x_i\beta)[(\frac{\gamma}{1-\gamma})\frac{1}{\sigma^2}]^{1/2}$

and $\frac{\partial F(W_i)}{\partial W_i} = \frac{1}{\sqrt{2\pi}} e^{-\frac{W_i^2}{2}}$ and $\frac{\partial W_i}{\partial\beta} = -x_i'[(\frac{\gamma}{1-\gamma})\frac{1}{\sigma^2}]^{1/2}$

Now, $$\frac{\partial L}{\partial\sigma^2} = \frac{n}{2\sigma^2} - \sum_{i=1}^{n} - \frac{1}{1-F(W_i)} \frac{\partial F(W_i)}{\partial W_i} \frac{\partial W_i}{\partial\sigma^2} - \frac{1}{2}(\frac{1-\gamma}{\gamma})^2 \sum_{i=1}^{n} W_i \frac{\partial W_i}{\partial\sigma^2} = 0 \tag{3.26}$$

---

56 Theil, H. (1971) Principles of Econometrics, John Wiley & Sons, Inc., New York (p.89).

where $\quad W_i = (y_i - x_i\beta)[(\frac{\gamma}{1-\gamma})\frac{1}{\sigma^2}]^{1/2}$.

and $\quad \frac{\partial W_i}{\partial \sigma^2} = -\frac{1}{2\sigma^2}[(\frac{y_i - x_i\beta}{\sigma})(\frac{\gamma}{1-\gamma})^{1/2}] = \frac{1}{2}\frac{W_i}{\sigma^2}$

and, $$\frac{\partial L}{\partial \gamma} = -\sum_{i=1}^{n} \frac{1}{1-F(W_i)} \frac{\partial F(W_i)}{\partial W_i} \frac{\partial W_i}{\partial \gamma} \qquad (3.27)$$

where $\quad W_i = (y_i - x_i\beta)[(\frac{\gamma}{1-\gamma})\frac{1}{\sigma^2}]^{1/2}$

and $$\frac{\partial W_i}{\partial \gamma} = \frac{1}{2}(\frac{y_i - x_i\beta}{\sigma})\frac{1}{\sqrt{\gamma}} \cdot \frac{1}{(1-\gamma)\sqrt{1-\gamma}}$$

$$= \frac{1}{2}\frac{W_i}{\gamma(1-\gamma)}$$

In practice, it is very difficult to solve the simultaneous equations (3.25) to (3.27) to obtain the ML estimators. The ML estimators can thus only be approximated by numerical methods. There are a number of methods for approximation; of these, the Newton Rapshen (NR) technique ensures convergence at a more rapid rate than most other techniques, as it is the only one that uses second order derivatives. In this technique, we start with a trial solution and find the errors involved; from this error, we choose the next trial solution so as to reduce the error; we proceed in this way until the solution is close enough to the ML estimator of the vector θ. But convergence depends on two factors, namely: (i) closeness of the trial solution θ_o to the final solution of the maximum of the likelihood function; and (ii) whether these successive estimators over-shoot the true solution or not. Kale,[57] to reduce this over-shooting,

57 Kale, B.K. (1962) 'On the solution of the likelihood equations by iteration process: the multiparameter case', Biometrica, Vol.49, (pp.479-86).

suggested a slight modification over NR technique, which involves controlling the movement of the successive estimators from the initial estimator through a pre-determined specified proportion of the change. The modified NR estimator is:

$$\theta_1 = \theta_o - \alpha\left[\frac{\partial^2 L(y;\theta_o)}{\partial\theta\partial\theta^1}\right]^{-1} \frac{\partial L(y;\theta_o)}{\partial\theta}$$

where $\frac{\partial L}{\partial\theta}$ and $\frac{\partial^2 L}{\partial\theta\partial\theta'}$ respectively are the first and second order partial derivatives of the likelihood function (3.24), evaluated at the initial parameter estimators θ_o; α represents the specified proportion of change and is a constant ranging from 0 to 1. Battese and Corra[58] used this modified NR estimator in their analysis.

Selecting the initial estimate θ_o in the neighbourhood of the maximum of the function may be done in the following way. It is reasonable to expect the estimates of the frontier function to be as high as the OLS estimates of the production function showing average technology. So, the initial estimator θ_o, is assumed to have respectively β_o,β_i's and σ^2 as the OLS estimates showing the intercept (β_o) and other parameters (β_i's) and the residual variance. Thus, the OLS estimates serve as lower bounds for the ML estimators. The only value which cannot be taken from OLS estimates is γ, and so different values of γ ranging from 0.1 to 0.9 are tried in the iterative technique. Iterations are carried out till the likelihood function (3.22) achieves its maximum value and the estimator associated with that maximum value of the likelihood function is the ML estimator, i.e., the parameters of the MFY or frontier function.

---

58 Battese, G.E. and G.S. Corra (1977).

Profit Function Analysis:

'For a given technology and a given endowment of fixed factors of production, the profit function expresses the maximised profit of a firm as a function of the prices of output and variable inputs and the quantity of the fixed factors of production.'[59] Profit is defined as the difference between total revenue and the total variable costs.

$$S = p_y f(y) - \sum_{i=1}^{m} p_i x_i \tag{3.28}$$

where S denotes profit; p_y and p_i's denote the unit price of output and variable inputs respectively; f(y) is the production function and x_i's are variable inputs in it. The marginal productivity conditions from (3.28) of a profit-maximising firm are:

$$p_y \cdot \frac{\partial f}{\partial x_i} = p_i \qquad i = 1,2,\ldots m \tag{3.29}$$

$$\text{i.e.,}\ \frac{\partial f}{\partial x_i} = {}^{p_i}/_{p_y} = r_i \tag{3.30}$$

where r_i means the normalised price of the i^{th} variable input.

In (3.30), there are m equations to solve for m unknown x_i's which yield maximum profit in (3.28). Solving (3.30) for x_i's, we get

$$\hat{x}_i = f_i(r,z) \qquad i = 1,2,\ldots m \tag{3.31}$$

where z represents the fixed inputs $x_{m+1},\ldots x_n$ in f(y). Substituting (3.31) in (3.28), we get the profit function,

$$\pi = p_y[f(\hat{x}_1,\ldots \hat{x}_m, x_{m+1},\ldots x_n) - \sum_{i=1}^{m} r_i \hat{x}_i] \tag{3.32}$$

Now $$\frac{\pi}{p_y} = f(\hat{x}_1,\ldots \hat{x}_m,\ldots x_n) - \sum_{i=1}^{m} r_i \hat{x}_i \tag{3.33}$$

59 Lau, L.J. and P.A. Yotopoulos (1972) 'Profit, supply and factor demand functions', American Journal of Agricultural Economics, Vol.54, No.1, (pp.11-18), (p.11).

In (3.33) the RHS is a function only of the normalised prices of variable inputs by output price and fixed factors of production, therefore,

$$\pi^* = g(r_1,\ldots r_m, x_{m+1},\ldots x_n) \qquad (3.34)$$

and is called a unit output price (UOP) profit function. As our concern here is an empirical application, there is no attempt to examine theoretical properties of the profit function in detail. However, some important theorems can be briefly given without proofs:[60]

a. There exists a one to one correspondence between the set of concave production functions and the set of convex profit functions.

b. Every concave production function has a dual which is a convex profit function.

c. The profit function estimates of the production parameter are more efficient than estimates obtained from a direct production function.

d. Shephard's lemma enables us to derive factor demand functions of variable inputs and the supply function from the UOP profit function, by differentiating (3.34).[61]

60 More information regarding theoretical properties of profit functions can be obtained from: Lau, L.J. (1972) 'Profit functions of technologies with multiple inputs and outputs', Review of Economics and Statistics, Vol.54, No.3, (pp.281-9), and

Fuss, M. and D.L. McFadden (eds.) (1978) Production Economics: A Dual Approach To Theory and Applications, Vol.2, North Holland Publishing Company, Amsterdam.

61 Equation (3.34) which expresses the unit output profit function in terms of the variable normalised input prices and fixed factors of production can be solved for variable factor demand function and output supply function, which are given respectively as:

$$x_i^* = -\frac{\partial g(r,z)}{\partial r_i} \qquad i = 1,\ldots m \qquad (3.35)$$

and from the definition of normalised profit (3.33),

$$T^* = g(r,z) - \sum_{i=1}^{m} \frac{\partial g(r,z)}{\partial r_i} \cdot r_i \qquad (3.36)$$

e. The UOP profit function is decreasing in the normalised prices of variable inputs and increasing in the fixed factor of production.

Cobb-Douglas Profit Function: The Cobb-Douglas production function with decreasing returns in variable inputs may be written as:

$$y = A \prod_{i=1}^{m} x_i^{\beta_i} \prod_{i=m+1}^{n} Z_i^{\alpha_i} \tag{3.37}$$

where y is the physical output of paddy measured in tonnes; x_i's and z_i's are variable and fixed factors of production respectively.

Now the UOP profit function for this Cobb-Douglas production function is:[62]

$$\pi^* = A^{(1-w)^{-1}} (1-w) \left[\prod_{i=1}^{m} \left(\frac{r_i}{\beta_i}\right)^{-\beta_i (1-w)^{-1}} \right] \left[\prod_{i=m+1}^{n} Z_i^{\alpha_i (1-w)^{-1}} \right] \tag{3.38}$$

where $w = \sum_{i=1}^{m} \beta_i < 1$

Taking natural logarithms on both sides of (3.38),

$$\ln \pi^* = \ln A^* + \sum_{i=1}^{m} \beta_i^* \ln r_i + \sum_{i=m+1}^{n} \alpha_i^* \ln Z_i \tag{3.39}$$

where $A^* = A^{(1-w)^{-1}} (1-w) \left[\prod_{i=1}^{m} \beta_i^{\beta_i (1-w)^{-1}} \right]$

$\beta_i^* = -\beta_i (1-w)^{-1} < 0 \qquad i = 1,2,\ldots m$

$\alpha_i^* = \alpha_i (1-w)^{-1} > 0 \qquad i = m+1, m+2,\ldots n$

---

62 This is obtained by substituting the variable factor demand function (3.35) and the output supply function (3.36) in the UOP profit function (3.33), thus,

$$\pi^* = T^* - \sum_{i=1}^{m} r_i x_i^*$$

The variable factor demand functions are given by the Shephard's lemma as,

$$\hat{x}_i = - \frac{\partial \pi^*}{\partial r_i} \qquad i = 1,2,...m \qquad (3.40)$$

Multiplying both sides of (3.40) by $- \frac{r_i}{\pi^*}$,

$$- \frac{r_i \hat{x}_i}{\pi^*} = \frac{\partial \ln \pi^*}{\partial \ln r_i} \qquad i = 1,2,...m \qquad (3.41)$$

In the context of the Cobb-Douglas production function, (3.39) becomes,

$$- \frac{r_i \hat{x}_i}{\pi^*} = \beta_i^* \qquad i = 1,2,...m \qquad (3.42)$$

Now the estimation of the empirical profit and factor demand functions can be carried out by estimating (3.39) and (3.42).

Since β_i^* appears in both (3.39) and (3.42), these two functions should be estimated jointly by imposing the condition that β_i^* are equal in both the equations.[63] The restricted Aitken estimation proposed by Zellner can be employed to estimate the parameters of (3.39) and (3.42) jointly.[64] In this study the parametric restrictions were imposed by Lagrange multipliers as used by Byron which differed from the approach of Lau and Yotopoulos.[65] Our approach of estimation enables us to find out which of the equality restrictions of β_i is not valid.

In the present study the profit function is used as an operational model to measure and compare economic efficiency and its components of

63 This is explained in detail in Appendix 3.2.

64 Zellner, A. (1962) 'An efficient method for estimating seemingly unrelated regression equations and tests for aggregation bias', Journal of American Statistical Association, Vol.57 (pp.348-68).

65 Byron, R.P. (1970) 'The restricted Aitken estimation of sets of demand relations', Econometrica, Vol.38, No.6 (pp.816-30).

technical efficiency and price (or allocative) efficiency for sample participants. The model is identical to the one used by Yotopoulos and Lau with Indian farm management data.[66] The profit function defined in (3.39) has been adjusted suitably to identify separately the components of technical and price efficiency.

Considering two groups of farms, say, large and small, their production functions can be written respectively as,

$$y^1 = A^1 f_1(x^1, Z^2); \; y^2 = A^2 f_2(x^2, Z^2) \tag{3.43}$$

with usual definitions of y, x and Z. Farm-specific technical efficiency is captured by the neutral differences in the production function, A^1 and A^2.[67] Two groups are equally technical efficient if $A^1 = A^2$. Now, the marginal condition for the two groups, assuming that they face different input prices, are given by,

$$\begin{aligned} \frac{\partial y^1}{\partial x_j^1} &= k_j^1 r_j^1 \qquad \text{where } k_j^1 > 0 \\ \frac{\partial y^2}{\partial x_j^2} &= k_j^2 r_j^2 \qquad \text{where } k_j^2 > 0 \qquad j = 1,2,\ldots m \end{aligned} \tag{3.44}$$

(3.44) enables us to allow interfarm differences in the ability to equate the value of the marginal products of the variable factors to their prices. In (3.44) k_j^i represent the farm and variable factor specific differences in managerial-entrepreneurial ability showing different degrees of equating

66 Yotopoulos, P.A. and L.J. Lau (1973) 'A test for relative economic efficiency: some further results', American Economic Review, Vol.63, No.1 (pp.214-23).

67 Inter-farm differences in technical efficiency within a group are assumed to be negligible.

the MVP and its price. Two groups are equally price-efficient with respect to all variable inputs if $k_j^1 = k_j^2$ for j = 1,2,...m.

In the context of the Cobb-Douglas form of production function (3.43), the UOP profit function related to it with technical and price efficiency parameter A^i and k^i is:[68]

$$\pi^i = A^{i(1-w)^{-1}} (1 - \sum_{j=1}^{m} \beta_j/k_j^i) [\prod_{j=1}^{m} (k_j^i)^{-\beta_j (1-w)^{-1}}]$$

$$[\prod_{j=1}^{m} \beta_j^{\beta_j (1-w)^{-1}}] [\prod_{j=1}^{m} (r_j^i)^{-\beta_j (1-w)^{-1}}] [\prod_{j=m+1}^{n} (Z_j^i)^{\alpha j (1-w)^{-1}}]$$

$$i = 1,2 \qquad (3.45)$$

i.e., $$\pi^i = A_*^i \prod_{j=1}^{m} (r_j^i)^{\beta_j^*} \prod_{j=m+1}^{n} (Z_j^i)^{\alpha_j^*} \qquad i = 1,2 \qquad (3.46)$$

where $$A_*^i = A^{i(1-w)^{-1}} (1 - \sum_{j=1}^{m} \beta_j/k_j^i) [\prod_{j=1}^{m} (k_j^i)^{-\beta_j (1-w)^{-1}}] [\prod_{j=1}^{m} \beta_j^{\beta_j (1-w)^{-1}}]$$

$$i = 1,2$$

$$k_*^i = (1 - \sum_{j=1}^{m} \beta_j/k_j^i)(1-w)^{-1} \qquad i = 1,2$$

$$\beta_j^* = -\beta_j (1-w)^{-1} < 0 \qquad j = 1,2,\ldots m$$

and $$\alpha_j^* = \alpha_j (1-w)^{-1} > 0 \qquad j = m+1, m+2, \ldots n$$

The factor demand functions, by Shephard's lemma are as,

$$x_j^i = -\frac{A^i}{k_j^i} \frac{\partial g(k^i r^i / A^i; Z^i)}{\partial r_j^i} \qquad \begin{matrix} i = 1,2 \\ j = 1,2,\ldots m \end{matrix} \qquad (3.47)$$

where $g(\cdot)$ is the UOP profit functions corresponding to production functions (3.43).

68 Yotopoulos, P.A. and L.J. Lau (1973) (pp.216-7).

The variable factor demand functions are given by (3.47) and by direct computation they are written as,

$$x_s^i = A^{i(1-w)^{-1}} (\beta_s/k_s^i r_s^i)\Big[\sum_{j=1}^{m} (k_j^i)^{-\beta_j(1-w)^{-1}}\Big]\Big[\prod_{j=1}^{m} (\beta_j)^{\beta_j(1-w)^{-1}}\Big]$$

$$\Big[\prod_{j=1}^{m} (r_j^i)^{-\beta_j(1-w)^{-1}}\Big]\Big[\prod_{j=m+1}^{n} (Z_j^i)^{\alpha_j(1-w)^{-1}}\Big] \qquad \begin{matrix} i = 1,2 \\ s = 1,2,\ldots m \end{matrix}$$

i.e.,

$$X_s^i = - A_*^i \beta_s^* (k_s^i)^{-1} (r_s^i)^{-1} (k_*^i)^{-1} \Big[\prod_{j=1}^{m} (r_j^i)^{\beta_j^*}\Big]\Big[\prod_{j=m+1}^{n} (Z_j^i)^{\alpha_j^*}\Big] \tag{3.48}$$

$$i = 1,2$$

$$s = 1,2,\ldots m$$

or by substitution from (3.47),

$$- \frac{r_s^i x_s^i}{\pi^i} = (k_s^i)^{-1} (k_*^i)^{-1} \ \beta_s^* = \beta_s^{*i} \qquad \begin{matrix} i = 1,2 \\ s = 1,2,\ldots m \end{matrix} \tag{3.49}$$

This means that the elasticities of variable inputs estimated from the variable factor demand functions (3.47) are equal to the respective elasticities estimated from profit function (3.46) only if, $(k_s^i)^{-1}.(k_*^i)^{-1}=1$.

<u>Empirical Profit Function</u>: Thus the estimating equations for the present study are:

$$\ln \pi = \lambda + \alpha_0^* D_1 + \beta_1^* \ln W + \beta_2^* \ln F + \beta_3^* \ln P + \beta_4^* \ln B + \alpha_1^* \ln L + \alpha_2^* \ln C \tag{3.50}$$

where π = UOP profit in Rs.

W = normalised wage for labour (manday) and is calculated, dividing the total wage paid to hired labour, by the total number of hired labour and then dividing this ratio by the unit price of paddy.

F = normalised fertiliser price and is worked out, dividing the total expenditure on fertiliser by the total amount of fertiliser expressed in Kgs. and normalising the ratio by UOP.

P = normalised pesticides price and is calculated by dividing the total amount spent on pesticides by total amount of pesticides expressed in Kgs. and normalising this ratio by UOP.

B = normalised wage for bullock pair day and is worked out by dividing the total expenditure on bullocks by the total pair of bullocks and further dividing this ratio by UOP.

L = cultivated area in acres.

C = capital flow defined in (3.8) above.

D_1 = 1 for small farms

= 0 otherwise

λ = $\ln A_*$

Factor demand functions can be written as,

$$\begin{aligned}
-\frac{Wx_1}{\pi} &= \beta_1^{*S} D_1 + \beta_1^{*L} D_2 \\
-\frac{Fx_2}{\pi} &= \beta_2^{*S} D_1 + \beta_2^{*L} D_2 \\
-\frac{Px_3}{\pi} &= \beta_3^{*S} D_1 + \beta_3^{*L} D_2 \\
-\frac{Bx_4}{\pi} &= \beta_4^{*S} D_1 + \beta_4^{*L} D_2
\end{aligned} \qquad (3.51)$$

where x_1 is total labour mandays hired;

x_2 = total chemical fertiliser used (Kgs.);

x_3 = total pesticides used (Kgs.);

x_4 = total bullock pair days;

D_1 = 1 for small farms and zero otherwise; and

D_2 = 1 for large farms and zero otherwise.

Tests for Relative Efficiency: The first hypothesis to be tested about the economic efficiency with the profit function is that there is equal relative economic efficiency among the small and large farm groups in the study area. This requires that the UOP profit functions of the small and large farm group and their variable factor demand functions coincide with each other. This implies that $A_*^1 = A_*^2$ in (3.46), and $\beta_s^{*L} = \beta_s^{*S}$. This equality will happen only if $A^1 = A^2$ and $k^1 = k^2$ in UOP profit functions (3.45). These linear relationships $A_*^1 = A_*^2$ and $\beta_s^{*L} = \beta_s^{*S}$ enable us to test for the two components of economic efficiency, namely, equal relative technical efficiency and price efficiency.

Testing equal relative economic efficiency empirically between small and large farms is therefore the same as examining whether parameters of the UOP profit function of small and large farms are the same. This is equivalent to testing whether the coefficient of the dummy variable differentiating the two profit functions, α_0^*, is zero in (3.50). It may be noted that it is possible for two farms to be equally efficient economically without being equally efficient technically or equally price efficient.[69] A test for equal relative price efficiency between small and large farms consists of examining whether both group of farms have the same

69 Ibid., (p.217).

price efficiency parameter, k_s, i.e., testing whether both small and large farms equate marginal value product to marginal cost of the variable factors of production to the same degree. This is equivalent to testing the hypothesis that the elasticities of variable inputs of small and large farms estimated from their factor demand functions are the same.

$$\beta_s^{*L} = \beta_s^{*S} \qquad s = 1,2,3,4$$

A test for equal relative technical efficiency consists of testing the joint hypothesis of economic efficiency and price efficiency mentioned above.

$$\alpha_0^{*} = 0 \text{ and } \beta_s^{*S} = \beta_s^{*L} \qquad (s = 1,2,3,4)$$

The next hypothesis is to test whether the farms (small or large) maximise their profits perfectly, equating marginal value products of the variable factors of production to their market prices which are specific to these farms (small or large). This is equivalent to testing whether the elasticities of variable factors of production estimated from the factor demand functions of a group of farm are equal to the respective elasticities estimated from their profit functions.

i.e., $$\beta_s^{*i} = \beta_s^{*} \qquad \begin{array}{l} i = 1,2 \\ s = 1,2,3,4 \end{array}$$

The above hypothesis is called absolute price efficiency of farms. All the above hypotheses were tested by incorporating the respective equality constraints in the estimation process using Aitken's generalised least squares method, so that the estimated coefficients exactly satisfy the conditions imposed by the null hypotheses. The estimation procedure is given in detail in Appendix 3.2.

CHAPTER 4

PHYSICAL PERFORMANCE OF THE HYVP

Experience with the HYVP for wheat in India showed that the contribution of research stations in evolving wheat varieties which achieve high yields under local production conditions, was a major factor for the spectacular production performance of the crop. "The release of Mexican wheat varieties to cultivators was preceded by comprehensive testing, field trials and demonstrations. However, in the case of rice, 'administrative action preceded development of scientific knowledge'. This was one of the important reasons for the poor performance of the HYVP for rice."[1] 'Knowledge concerning the numerous small but crucial changes which need to be introduced in rice agronomy was not available at the time the HYV Programme was initiated in rice and even today such knowledge is not widespread among extension workers'.[2] Further, lack of suitable paddy varieties led to problems of pest and disease attack especially in kharif, the main paddy season. This could be tackled to a considerable extent by evolving HYVs which incorporated resistance genetically or which modified other biological characteristics of seeds, e.g., reduced the duration of the growing season, and thereby reduced the incidence and severity of pest attack.

Thus, the technology-based strategy of evolving location-specific HYVs (LSVs) has come to be recognised as being crucial to the success of

---

1 FAO (1975) Introduction and Effects of High-Yielding Varieties of Cereals in India, FAO Publications, Rome (p.24).

2 Swaminathan, M.S. (1969).

the HYVP for rice. Physical performance is of course one of the components of success of the modified new strategy. It can be assessed by measuring the gain in yield of the newly evolved LSVs over yields of the existing HYVs in that area. The difference in yields is described here as the 'varietal yield gap'.

Among scientists in developing countries concerned with rice there is a general belief that few farmers are fully exploiting the potential of rice production technology, and that therefore, farm rice yields are far below their potential level.[3] It is our aim here, to ascertain the maximum feasible yield under farm conditions in the study area. Barker and others have argued that soil health problems, improper water management, inadequate application of fertiliser and plant protection chemicals, lack of credit facilities, deficiencies in input supply and lack of institutional infrastructure are the important bio-physical and socio-economic factors preventing the farmer from exploiting the full potential of the technology, and that those with easy access to inputs and credit and who are performing cultural practices correctly will achieve higher yields. Thus, heterogeneous production conditions are limiting rice production. It is hypothesised here, based on the PEO-ANU preliminary evidence, that under homogeneous and favourable production and institutional conditions, yield performances will be impressive and show minimal variation. Our choice of survey area and sample participants will allow this to be tested.

Sections below examine the contribution of LSVs, and measure the magnitude of the 'varietal yield gap', then test the hypothesis of minimal

---

3 See Barker, R., Kauffman, H.E. and R.W. Herdt (1975) 'Production Constraints and Priorities for Research', paper presented at the International Rice Research Conference, IRRI, Los Banos, April 21-25.

variation in yields under homogeneous production conditions, and finally reach conclusions concerning physical performance.

The Contribution of LSVs

It has been recognised in recent years that paddy breeding research must be decentralised to develop varieties that are location-specific, and season-specific within a location, with due account taken of seasonal duration, variations in timing and control of water supplies and biological variation in pest and disease types.[4] Decentralisation of research has proceeded to the state level and to smaller area units within states, with some states more advanced than others. Tamil Nadu was found to be one of the most progressive.[5] The state has been divided into six broad agro-climatic regions, within each of which, production conditions were homogeneous in terms of a number of key criteria[6] (Table 4.1).

Rice research at the Paddy Breeding Station at the Tamil Nadu Agricultural University (TNAU), Coimbatore was intensified in 1969 with its recognition as the zonal headquarters for the Southern Peninsula by the All-India Co-ordinated Rice Improvement Project (AICRIP). The main objective of the programme of research at this centre is to carry out multi-disciplinary and multi-locational co-ordinated research on rice.[7] Thus paddy breeding had been proceeding there for a number of years to

---

4 PEO-ANU (1977) (p.15).

5 Ibid., p.38 and p.40.

6 Subramanian, A. (1970) 'Agro-climatic regions of Tamil Nadu and regional research stations', Tamil Nadu Agricultural University, Coimbatore, (mimeo).

7 Subramanian, A. et al. (1971) 'Performance of new high yielding varieties of rice at Coimbatore', The Madras Agricultural Journal, Vol. 58, No.7, (pp.649-58).

TABLE 4.1

AGRO-CLIMATIC REGIONS OF TAMIL NADU

Region	Rainfall	Areas (districts)
I	35" - 50"	Chingleput, a part in North Arcot, South Arcot and Tiruchirapalli.
II	30" - 35"	Salem, a part of Tiruchirapalli, major portions of North Arcot and Dharmapuri excluding adjoining hills and Hosur taluk.
III	25" - 30"	Coimbatore, Hosur taluk of Dharmapuri, Karur taluk and southern portion of Tiruchirapalli, northern half of Madurai and a part of Pudukottai.
IV	35" - 40"	Thanjavur, a portion in Tiruchirapalli and Pudukottai.
V	25" - 35"	Thirunelveli, Ramanathapuram, Kanyakumari and a part in Madurai.
VI	40" - 200" (hilly regions)	Nilgiris, Anamalais, Palnis and Podhigai Malai.

Source: Subramanian, A. (1970).

develop LSVs for each of these six zones, by cross-breeding exotic HYVs (EVs) with local and local-improved varieties (LIs), incorporating characteristics of the latter, to produce progeny better adapted to local production conditions and marketing requirements. A number of LSVs were released by the Coimbatore Paddy Breeding Station for large scale cultivation. Among them, ADT-31 (IR8 x Culture 340), and CO-37 (TN-1 x CO-29) also known as Vaigai, were the two LSVs most recently developed at this station for the production conditions of irrigated areas in Coimbatore district, including Gobichettipalayam block.[8] Prior to the introduction of these LSVs the most popular EV, IR20, developed at the International Rice Research Institute (IRRI) and introduced in 1972, was grown almost exclusively in both seasons in Gobichettipalayam block.[9] Our analysis will therefore evaluate progress made in the study area with these two new LSVs by comparing their performance with that of the existing EV, IR20, at the farm level.

Mean Input Levels and Yields: Table 4.2 shows the differences between the per acre average of input applications, yields and size of holdings for sample farmers growing LSVs and EVs in kharif. It shows that both groups of farmers were using almost equal amounts of inputs, yet the yield levels differed substantially. The difference between average yields was 0.8 tons per acre and was significant statistically at the 1 per cent level.[10]

---

8 Throughout the study LSVs refer to both ADT-31 and CO-37.

9 To be strictly accurate, IR20 was only partly exotic. Its parents were TN-1 and TKM-6. TKM-6, for a long popular local variety in Tamil Nadu, was introduced to IRRI's cross-breeding programme in the Philippines. This probably accounts for much of IR20's popularity in Coimbatore district, however, experience showed that it exhibited only some of the characteristics that are required for successful adaptation and high yield performance in Coimbatore district.

10 To test the significance of differences between the means, the standard errors of differences were computed by comparing means of samples with equal variances. Consider the statistic,

$$t = \frac{\bar{x}_1 - \bar{x}_2}{S_{\bar{d}}}$$

Where $\bar{x}_1$ and $\bar{x}_2$ are sample means with variances S_1^2 and S_2^2, the pooled variance $S^2 = \frac{(m_1-1)S_1^2 + (n_2-1)S_2^2}{(n_1-1) + (n_2-1)}$ and the sample variance for the difference of sample means is $S_{\bar{d}}^2 = (S^2/m_1 + S^2/m_2)$. This follows a t-distribution with $(n_1 + n_2-2)$ degrees of freedom and the null hypothesis

TABLE 4.2

REPORTED AVERAGE INPUT APPLICATIONS PER ACRE

BY SAMPLE FARMERS GROWING EVs AND LSVs IN KHARIF SEASON

INPUTS AND FARM CHARACTERISTICS	EVs	LSVs	t-ratio
Sample Size	41	50	
Farm size (Ac)	2.40	3.85	2.36**
Hired labour (Mandays)	209.49	180.72	1.83
Nitrogen (Kgs.)	45.71	49.82	0.66
Phosphorous (Kgs.)	23.07	21.06	1.27
Potassium (Kgs.)	20.73	21.46	0.44
Pesticides expenditure (Rp)	118.90	111.60	0.61
Seed expenditure (Rp)	52.70 (26.38)	54.90 (26.98)	1.12
Expenditure on other inputs (Rp)	263.60	278.85	0.90
Yield (ton/acre)	1.57	2.37	9.56*

Notes: Figures in parentheses refer to seed rate in kgs. per acre at mean level.

* significant at the 1 per cent level.

** significant at the 5 per cent level.

The average farm size operated by LSV growers was bigger than that of EV growers and in this case, the difference was significant at the 5 per cent level. Though EV growers seem to be using more hired labour mandays than the LSV growers, the difference was not statistically significant. The average doses of chemical fertilisers applied per acre by both the LSV and EV cultivators exceeded recommendations, but differences between them in

10 (Continued)

of no difference can be accepted or rejected depending on whether the calculated 't' is less than or greater than tabulated 't' at a particular level of confidence. [Blalock, H.M. (1972) Social Statistics, McGraw Hill, New York.]

application levels were again not significant. Mean expenditures on seeds and pesticides were almost the same for the two groups.

Thus, assuming the same cultural practices and application levels of all inputs for both varieties, it was possible to measure by how much total production of paddy could be increased among sample participants by replacing EV with LSV seed. If the average yield increase of 0.80 tonnes per acre is multiplied by the total area under EVs in kharif (98.39 acres), the total production of paddy could be increased to almost 79 tonnes in the study area. This suggests that there is scope for increasing paddy production substantially by making a switch from EVs to LSVs, without changing the infrastructure. Thus, the data strongly suggest the superiority of LSVs in increasing paddy production, but show that reaping full benefits from LSVs will require all farmers to switch to them.[11] Identification of the factors responsible for this superiority of the LSVs over the EVs has been attempted below, by using production function analysis developed in the previous chapter.

<u>Identifying Varietal Yield Gap</u>: In identifying the varietal yield gap, it is necessary first to see which of the factors of production are responsible, and second, what contribution each is making to this. Utilising the 'average analysis' by measuring the magnitude of yield gain from adopting LSVs, it is hypothesised that the shift that takes place between production functions is of the Hick's neutral type, without change to the factor elasticities. In other words, the hypothesis is that the conventional factors of production are not responsible for this varietal yield gap.

---

11 Hence one needs to know why some farmers lag in the adoption process. In the study area, in fact, only 11 per cent of the total area was under EVs in kharif 1977 thus showing that IR20 was fast losing its popularity.

This is tested below, using the dummy variable technique in the production function.

The production function, as developed in Chapter 3, is rewritten here as,

$$Y = f(x_1, x_2, x_3, x_4) \tag{4.1}$$

where Y represents yield per acre of paddy cultivated;

x_1 is labour mandays used per acre;

x_2 is per acre expenditure on fertiliser;

x_3 is per acre expenditure on other inputs; and

x_4 serves as capital flow variable per acre.

In many parts of India as elsewhere in South, South East Asia and the Pacific regions, the incidence of brown plant hopper (BPH) attack is a major determinant of yield and production. Attempts have been made to incorporate resistance through cross-breeding, but it has been found that, owing to the number of bio-types of BPH, no one resistant variety will retain its immunity against all bio-types. Breeding for resistance has therefore become an important part of the location-specific research package.

BPH attack was reported during the kharif season under survey and affected both LSVs and EVs. In fact, BPH attack had been reported ever since the kharif season of 1973. Though the rabi crops were also subject to BPH, attack was rare and damage was negligible. Incidence during the kharif season prompted sample participants to take precautionary measures against BPH from 1974 onwards. Almost all used the recommended preventive doses of pesticides and as a result the attacks were not as severe as those reported in other areas of Tamil Nadu. However, these preventive measures by no means eliminated the incidence of BPH attack. This necessitated participants taking curative measures as well. A major problem with the pesticides is that over time their effectiveness usually declines, as the pests learn how to cope with them through selective breeding.

Since all sample participants had applied pesticides, as recommended by the extension officials, representation of plant protection in equation (4.1) either in monetary or physical terms could not explain yield differences significantly. In this analysis, therefore, a dummy variable (D_2) was included to take account of this fact, utilising data from personal field observations and from questionnaires. The value of unity was given to instances where the attack was not severe, and zero was given otherwise. The dummy variable in depicting the severity of the attack thereby reflects too the susceptibility of the varieties and the effectiveness of protective measures taken by farmers. It enters the production function as a shift variable, implying that the absolute difference in yield between fields severely attacked and those pest free or mildly attacked is independent of the quantities of inputs included in equation (4.1).

A varietal dummy (D_1) was also introduced into the production function by assigning values of unity to LSVs and zero to EVs. The co-efficients of the dummy variables together with the constant term provide an estimate of the shifts in the value of yield, the dependent variable, (y). The Cobb-Douglas functional form was assumed for equation (4.1) with dummy variables as defined above.[12]

---

12 The lower case letters of y and x represent logarithms of Y and X.

$$y = \alpha + \sum_{i=1}^{2} \alpha_i D_i + \sum_{i=1}^{4} \beta_i x_i + u \tag{4.2}$$

where u represents the disturbance term with $N(0,\sigma^2)$.

The stability of yield parameters between LSVs and EVs has been examined by introducing intercept and slope dummies[13] in the production function equation (4.2). Depending upon the statistical significance of the estimated differential intercept and slope coefficients, we can test the hypothesis of Hick's neutral technical progress.

$$y = \alpha + \sum_{i=1}^{2} \alpha_i D_i + \alpha_3 D_{12} + \sum_{i=1}^{4} (\beta_i + \beta_i D_i) x_i + u \tag{4.3}$$

where D_{12} is the differential of D_2 which is obtained by $D_1 \times D_2$. Table 4.3 shows that the slope coefficients are stable between LSVs and EVs, but the differences in estimates of D_1 and D_2 are statistically significant.[14] We can therefore accept our hypothesis that the yield curve of LSVs has shifted neutrally in relation to that of EVs. This implies that the conventional factors of production are not responsible for the varietal yield gap and only variety and BPH attack are contributing to this gap.

The next step in the analysis, was to find out the contribution of each of these factors to this varietal yield gap. Assuming the stability of the slope, and only differentiating BPH attack by variety, (4.3) can be written as,

$$y = \alpha + \sum_{i=1}^{2} \alpha_i D_i + \alpha_3 D_{12} + \sum_{i=1}^{m} \beta_i x_i + u \tag{4.4}$$

---

13 Gujarati, D. (1970) 'Use of dummy variables in testing for equality between sets of coefficients in linear regression: a generalisation', The American Statistician, Vol.24, No.5, (pp.18-22).

14 It is possible that multicollinearity among the explanatory variables might have made some of the differential coefficients insignificant.

TABLE 4.3

TESTS OF THE STABILITY OF SLOPE AND INTERCEPT BETWEEN LSVs AND EV USING AN ESTIMATED COBB-DOUGLAS PRODUCTION FUNCTION

Variables	Parameter
α (constant)	0.5948** (0.2233)
D_1 (Varietal dummy)	1.4590* (0.3724)
D_2 (BPH control dummy)	0.1219** (0.0328)
D_{12} (Difference in D_2)	0.2217** (0.0821)
$\ln X_1$ (Labour)	0.0696 (0.0562)
$\ln X_2$ (Fertiliser application)	0.0466 (0.0972)
$\ln X_3$ (Capital flow)	0.0123** (0.0034)
$\ln X_4$ (Other inputs)	0.1352** (0.0542)
$D_1 \ln X_1$ (Diff. in X_1)	-0.0683 (0.0814)
$D_2 \ln X_2$ (Diff. in X_2)	-0.0276 (0.1324)
$D_3 \ln X_3$ (Diff. in X_3)	0.0022 (0.0113)
$D_4 \ln X_4$ (Diff. in X_4)	-0.0847 (0.0906)
$\bar{R}^2 = 0.7242$	

Notes: Figures in parentheses are standard errors of estimates.

* significant at the 1 per cent level.

** significant at the 5 per cent level.

The results (Table 4.4) show that the estimates of coefficients of labour, other inputs and capital are positive and significant at the 5 per cent level. They indicate that 1 per cent increase in labour

TABLE 4.4

ESTIMATED PARAMETERS OF COBB-DOUGLAS PRODUCTION FUNCTION FOR SAMPLE PARTICIPANTS GROWING LSVs AND EVs IN KHARIF SEASON

Variable	Parameter
α (constant)	0.1009^{**} (0.0334)
D_1 (Varietal dummy)	0.3092^{*} (0.0421)
D_2 (BPH control dummy)	0.1095^{**} (0.0420)
D_{12} (Differential BPH control)	0.1004^{**} (0.0478)
$\ln X_1$ (Labour)	0.0279^{**} (0.0097)
$\ln X_2$ (Fertiliser application)	0.0052^{***} (0.0027)
$\ln X_3$ (Capital)	0.0103^{**} (0.0048)
$\ln X_4$ (Other inputs)	0.0118^{**} (0.0055)
$\bar{R}^2 = 0.7288$	

Notes: Figures in parentheses are standard errors of estimates.
* significant at the 1 per cent level.
** significant at the 5 per cent level.
*** significant at the 10 per cent level.

mandays increased yield by 0.03 per cent,[15] whereas a 1 per cent increase in other inputs increased yield by 0.01 per cent and that a 1 per cent

15 At this stage, however, it is difficult to differentiate which of the labour inputs - hired or family - is to be increased.

increase in capital increased yield by 0.01 per cent for LSVs and EVs. The results further show that the fertiliser coefficient is 0.01 and is significant at 10 per cent level only for both varieties. All these estimates indicate that yield of both varieties could be increased only by small amounts by increasing the application of these inputs. The results further show that the estimates of the coefficients of D_2 and D_{12} are statistically significant, at the 5 per cent level. This means that the effectiveness of BPH control increased the net yield considerably, but in the case of LSVs the increase was more substantial. The coefficient of D_1 is significant at the 1 per cent level and this implies that the net increase in yield from using LSVs was much higher than by using EVs. Thus the significant differential coefficients of BPH control, D_{12}, and the significant varietal dummy D_1 show that the higher yield inherent in the genetic characteristics, of LSVs, and their other biological characteristics which have a positive influence on BPH control, are the two major factors explaining the varietal yield gap.

The crucial factor explaining the difference in the effectiveness of BPH control between the varieties appeared to be the difference in their maturity period. The LSVs mature earlier and the shorter season effectively cuts off part of the build-up period of BPH. By contrast, there seems to be a coincidence between the build-up of BPH and the longer maturity period of EVs that is favourable to the BPH and results in greater damage. The pesticides are not able to control BPH successfully in the case of EVs, owing to the greater intensity of build-up over the longer period of maturity, while the shorter duration of the LSVs enables pesticides to work more effectively.

On the whole, the results show that there was a neutral upward shift in the paddy production with the substitution of LSVs for EVs and BPH reduced EV more than LSV yields. Thus the higher yielding characteristics inherent in the genetics of LSVs and their shorter duration were the important factors explaining the varietal yield gap. The combination is of great importance in the quest for increased paddy production in the country. It also brings increased income to farmers cultivating LSVs, and an increased supply of rice to the market. It, therefore, seems reasonable to assume that the lack of LSVs was previously the major constraint restricting the farmers from achieving the potential of the HYVP.

Farmer Yield Gap: Our survey revealed that sample farmers cultivating under homogeneous conditions of production varied in their performance. This implies that even with the adoption of LSVs, further realisation of the potential of the HYVP is still possible. However, it should also be borne in mind that variation in performance among the participants producing under homogeneous conditions could also happen because of either an invalid assumption of homogeneity in the study area or from an unknown random factor.[16] Our hypothesis of minimal variation in yields among farmers cultivating under homogeneous conditions is tested below.

We defined above the maximum feasible yield (MFY) in the farmer's environment as one realised by those who follow the programme recommendations very closely. With estimation of the MFY from field data, comparisons can be made with the production function representing the average technology[17].

16 This is tested statistically by estimating the parameter γ in the maximum feasible yield function in the following pages.

17 This refers to the production function (4.4) which was estimated through ordinary least squares (OLS) technique. For a detailed discussion of this average production function, see Aigner, D.J. and S.F. Chu (1968) and Timmer, C.P. (1970). 'On measuring technical efficiency', Food Research Institute Studies, Vol.IX, No.2, (pp.99-171).

of the area. Calculation of difference between the MFY and actual yield obtained by individual farmers, which is described as the farmer yield gap in this study, enables analysis of factors acting as constraints.

It is assumed that the yield a farmer can achieve, using the available knowledge of the technology in the study area, is the maximum feasible yield, and is that obtained through use of the best practices and techniques. This implies that, if the production technology of each sample participant is raised to the best known practices and techniques available in that area, then all would be able to produce at this maximum level, given similarity in other conditions of production. This also means that a number of sample participants do not produce the greatest possible output from a given set of inputs, and are therefore not technically efficient.[18] These differences in technical efficiency could happen either accidentally, from random factors, or because of various socio-economic and biological factors. This is tested statistically when estimating the MFY production function.[19]

The MFY production function which is estimated using the maximum likelihood technique,[20] can be written from (4.4) as:

$$y = \alpha + \sum_{i=1}^{2} \alpha_i D_i + \alpha_3 D_{12} + \sum_{i=1}^{4} \beta_i x_i + u + v \qquad (4.5)$$

The definitions of the variables, here, are the same as in (4.4) except for u and v. In (4.5), u is assumed to be non-positive, reflecting the fact

---

18 The concept of technical efficiency is dealt with in detail in the next chapter, when the efficiency of sample participants is compared.

19 Muller assumed that differences in technical efficiency were not accidental but did not test this statistically. [Muller, J. (1972).]

20 This is different from the estimation of production function (4.4) which describes a kind of average of practices and techniques used in the study area.

that each farm's yield must lie on or below the MFY function. Any such deviation is the result of the farm's lack of use of the best practices. But, the MFY function itself can vary randomly over time, and so it is stochastic with random disturbance v describing, for example, weather, topography and errors in measurement and observations.[21] Further, it is assumed that u is distributed independently of v and follows a truncated normal distribution. v is distributed independently and normally with N $(0,\sigma^2)$. This specification enables estimation of γ, the ratio of the variance of u to the total variances of (u + v), so as to find out, on the basis of the size of γ, whether the differences in technical efficiency were actual or accidental. The smaller the ratio, the higher is the probability of differences being accidental.

The parameters of the MFY production function (4.5) were estimated using the maximum likelihood estimation (MLE) procedure described above in Chapter 3, and the results are presented in Tables 4.5 and 4.6 for kharif and rabi seasons respectively. The estimates of both slope and intercept of function (4.4) obtained by OLS were assumed as a lower-bound to start with, and 0.5 and the residual mean square for OLS were taken as γ and σ for MLE in both the seasons. The parameter estimates corresponding to the lowest value of the likelihood function were noted as the maximum likelihood estimates for kharif and rabi.

The interesting and important result (Table 4.5) is that the estimate of γ is larger (0.9309) and statistically significant. This

---

21 Aigner, D.J., et al. (1977). Marschak and Andrews in fact first suggested that the sum (u + v) described the technical efficiency and the will, effort and luck of a producer. [Marschak, J. and W.J. Andrews (1944) 'Random simultaneous equations and the theory of production', Econometrica, Vol.12 (pp.143-205).]

TABLE 4.5

ESTIMATED PARAMETERS OF MAXIMUM FEASIBLE YIELD FUNCTION (FRONTIER PRODUCTION FUNCTION) FOR SAMPLE PARTICIPANTS GROWING LSVs AND EVs IN KHARIF SEASON

Variable	Parameter
α (constant)	0.2403** (0.1171)
D_1 (Varietal dummy)	0.3096* (0.0440)
D_2 (BPH control dummy)	0.1105** (0.0504)
D_{12} (Differential BPH control)	0.1010** (0.0493)
$\ln X_1$ (Labour)	0.0286** (0.0108)
$\ln X_2$ (Fertiliser application)	0.0054*** (0.0032)
$\ln X_3$ (Capital)	0.0104** (0.0051)
$\ln X_4$ (Other inputs)	0.0124** (0.0057)

Log likelihood function = -9.1675

γ = 0.9309 (0.0973)

σ^2 = 1.2502 (0.4379)

Notes: Figures in parentheses are standard errors of estimates.

* significant at the 1 per cent level.

** significant at the 5 per cent level.

*** significant at the 10 per cent level.

TABLE 4.6

ESTIMATED PARAMETERS OF MAXIMUM FEASIBLE YIELD FUNCTION FOR SAMPLE PARTICIPANTS GROWING EVs AND LIs IN RABI SEASON

Variable	Parameter
α (constant)	0.2062^{**} (0.0596)
D_1 (Varietal dummy)	0.1261^{**} (0.0601)
D_2 (BPH control dummy)	0.0962^{**} (0.0473)
$\ln X_1$ (Labour)	0.0428^{**} (0.0217)
$\ln X_2$ (Fertiliser application)	0.0075^{**} (0.0037)
$\ln X_3$ (Capital flow)	0.0113^{**} (0.0054)
$\ln X_4$ (Other inputs)	0.0130^{**} (0.0057)

Log likelihood function = -12.0376

γ = 0.8101^{*} (0.1604)

σ^2 = 1.7605^{**} (0.5284)

Notes: Figures in parentheses are standard errors of estimates.

* significant at the 1 per cent level.

** significant at the 5 per cent level.

implies that the variation of a farm's yield from the MFY arises not from any chance factor, but mainly from differences in its lack of use of best practices. The parameters of (4.5) estimated by MLE seem to be the same as those of (4.4) estimated through OLS for the average practice technique, except for the constant term α, which is as expected. The constant term of (4.5) is 138 per cent higher than that of (4.2) and this means that the best practice production function has shifted neutrally (Hick's neutral) from the average production function in kharif. Meeusen and Broeck, and Battese and Corra, obtained the same result of a neutral shift.[22] However, this neutral shift could be because of the nature of the technique chosen to estimate the frontier production function.

It is important to note that the MFY for LSV (2.83 tons/acre) in kharif was very close to the experimental LSV yield (2.92 tons/acre) achieved by the Paddy Breeding Station of the Tamil Nadu Agricultural University (Table 4.7), and is greater than the experimental yield obtained by the Aduthurai Research Station in Tanjore district (Figure 4.1). These comparisons strongly suggest that at least some of the sample participants were exploiting the potential of the modified HYVP to the full and supports the hypothesis of Schultz, Barker and others that if the constraints of production conditions are removed, with the improvement of credit, input distribution, adaptive research, extension etc., farmers will show the best production performance.

In rabi season, the estimate of γ was 0.7250, (Table 4.6) and is significant at the 5 per cent level. This means that the farm's yield

---

22 Meeuson, W. and J.V.D. Broeck (1977) 'Efficiency estimation from Cobb-Douglas production functions with composed error', International Economic Review, Vol.18, No.2, (pp.435-44). Battese, G.E. and G.S. Corra (1977).

TABLE 4.7

EXPERIMENTAL AND MAXIMUM FEASIBLE YIELDS OF
LSVs AND EVs IN KHARIF SEASON
(ton/acre)

Variety	Source	Yield
ADT-31 (LSV)	Calculated from the MFY function estimated for sample participants	2.83
	Paddy Breeding Station, TNAU, Coimbatore	2.92
	Aduthurai Research Station, Tanjore District	2.02
IR20 (EV)	Calculated from the MFY function estimated for sample participants	1.89
	Paddy Breeding Station, TNAU, Coimbatore	2.43

Source: Information supplied by the crop specialist of the Paddy Breeding Station, Coimbatore and Aduthurai through an official communication to the author.

deviation from the MFY in that season was mostly caused by the participants' lack of use of best practices. The model estimated by OLS and MLE methods for rabi season was like that of equations (4.4) and (4.5) respectively, with the absence of D_{12}[23] and a difference of definition of D_1. In this

23 Estimation of the production function for rabi with differential intercept and slope coefficients was carried out. Results (Appendix 4.1) showed no significant differences in slope and in D_2 between the EV and LI functions, and differed only by variety as shown through D_1.

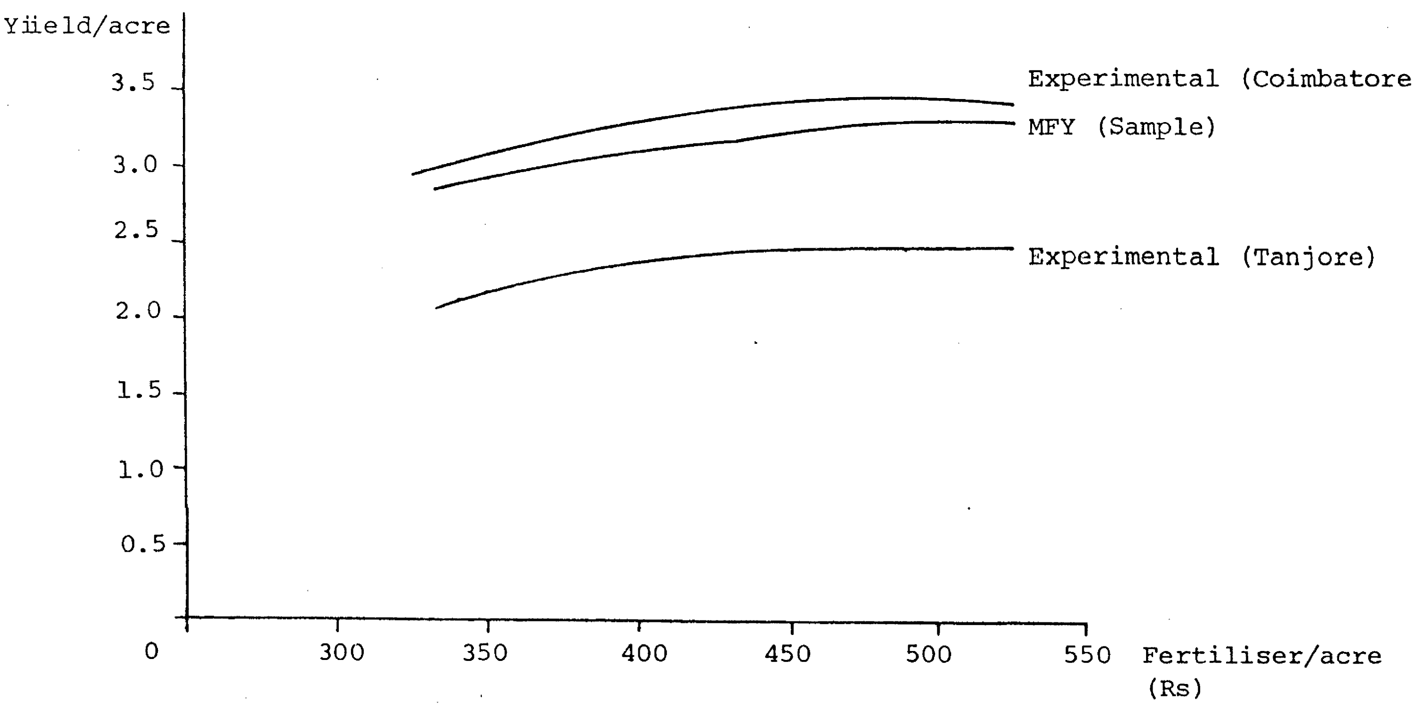


FIGURE 4.1: Yield curves of LSVs in kharif season

case, the varietal dummy D_1 takes the value unity if the farm cultivated EVs and zero otherwise. Comparisons of the estimates by OLS technique[24] (Table 4.8) with that of MLE procedure (Table 4.6) reveals that the best practice technique function shifted neutrally from the average production function.

TABLE 4.8

ESTIMATED PARAMETERS OF COBB-DOUGLAS PRODUCTION FUNCTION FOR SAMPLE PARTICIPANTS GROWING EVs AND LIs IN RABI SEASON

Variable	Parameter
α (constant)	0.1020** (0.0342)
D_1 (Varietal dummy)	0.1234** (0.0526)
D_2 (BPH control dummy)	0.0937** (0.0425)
$\ln X_1$ (Labour)	0.0424** (0.0192)
$\ln X_2$ (Fertiliser application)	0.0073** (0.0034)
$\ln X_3$ (Capital flow)	0.0112** (0.0049)
$\ln X_4$ (Other inputs)	0.0127** (0.0048)

$\bar{R}^2 = 0.7300$

Notes: Figures in parentheses are standard errors of estimates.

** significant at the 5 per cent level.

---

24 They were used as lower bound estimates for MLE technique.

Factors Responsible for the Farmer Yield Gap: Actual farm yields, the MFY calculated with the MFY production function, and the difference between these for sample participants growing HYVs and local improved varieties (LIs) in kharif and rabi seasons are given in Tables 4.9 and 4.10 respectively. These results (Tables 4.9 and 4.10) show that in both seasons, there were considerable differences between the MFY and actual yields of participants, (Figure 4.2).

As demonstrated statistically above, these productivity differences were mainly related to sample participants' lack of use of best practices. This could imply that the homogeneity assumption for production conditions is not valid for the study area, and that there could be differences in the availability and use of inputs. However, our survey suggests that the homogeneity assumption is valid for the conventional inputs, as almost all participants used either recommended levels or more of these inputs. Furthermore, since the paddy fields in the study area were contiguous and were therefore subject to the same micro-climate. Hence, the homogeneity assumption could only be invalid in relation to the use of non-conventional factors directly related to the technical efficiency of farms. One such basic factor, related to technical efficiency, is farmer knowledge of the HYVP. Differences in yield could occur either because of a lack of complete knowledge about the HYVP, or because the available technology was not utilised correctly. The latter can, in fact, be considered as absence of full information about the programme.[25] Identification of the

25 This is different from Muller's assumption of information leading to a gap in production. He did not consider the possibility of knowing the technology fully, but not using it correctly. [Muller, J. (1972).]

TABLE 4.9

ACTUAL YIELD AND ESTIMATED MAXIMUM FEASIBLE YIELD FOR THE SAMPLE PARTICIPANTS GROWING LSVs AND EVs IN KHARIF SEASON

(tons/acre)

Farm No. (1)	MFY (2)	Actual Yield (3)	Difference (2)-(3) (4)	% of Difference (5)
1	2.493	2.29	0.203	8.87
2	2.789	2.59	0.199	7.69
3	2.730	2.73	0.000	0.00
4	2.723	2.60	0.123	4.73
5	2.734	2.60	0.134	5.16
6	2.576	2.32	0.256	11.04
7	2.459	2.08	0.379	18.23
8	2.691	2.34	0.351	15.00
9	2.902	2.50	0.402	16.08
10	2.720	2.60	0.120	4.62
11	2.723	2.60	0.123	4.73
12	2.696	2.36	0.336	14.24
13	2.677	2.34	0.337	14.41
14	2.620	2.28	0.340	14.92
15	2.650	2.65	0.000	0.00
16	2.370	1.92	0.450	23.44
17	2.381	2.08	0.301	14.48
18	2.410	2.10	0.310	14.77
19	2.280	1.90	0.380	20.00
20	2.870	2.50	0.370	14.80
21	2.820	2.52	0.300	11.91
22	2.627	2.29	0.337	14.72
23	2.535	2.51	0.025	1.00
24	2.672	2.34	0.332	14.19
25	2.920	3.01	-0.090	-3.09
26	2.860	2.86	0.000	0.00
27	2.390	2.08	0.310	14.51
28	1.865	1.60	0.265	16.56
29	2.707	2.37	0.337	14.22
30	2.380	2.08	0.300	14.43
31	2.822	2.47	0.352	14.26
32	2.412	2.10	0.312	14.86
33	2.790	2.66	0.130	4.89
34	2.888	3.00	-0.112	-3.88
35	2.729	2.60	0.129	4.97
36	2.661	2.34	0.321	13.72
37	2.829	2.47	0.359	14.54
38	2.624	2.29	0.334	14.59
39	2.890	2.78	0.110	3.96
40	2.542	2.11	0.432	20.47

TABLE 4.9 (Cont'd)

41	2.979	2.60	0.379	14.58
42	2.865	3.04	-0.175	-6.11
43	2.842	2.49	0.352	14.14
44	2.500	2.17	0.330	15.21
45	2.371	2.07	0.301	14.55
46	2.735	2.60	0.135	5.20
47	2.492	2.08	0.512	19.81
48	2.385	2.08	0.305	14.67
49	1.730	1.46	0.270	18.49
50	2.420	2.42	0.000	0.00
51	2.420	1.73	0.690	21.31
52	1.781	1.56	0.221	14.17
53	1.972	1.82	0.152	8.36
54	2.107	2.04	0.067	3.29
55	1.999	1.86	0.139	7.48
56	1.694	1.44	0.254	17.64
57	2.180	2.20	-0.020	0.92
58	2.170	2.17	0.000	0.00
59	2.460	2.17	0.290	13.37
60	1.492	1.23	0.262	21.30
61	2.423	2.01	0.413	20.55
62	1.530	1.30	0.230	17.70
63	1.820	1.66	0.160	9.64
64	1.672	1.50	0.172	11.47
65	1.640	1.13	0.510	23.31
66	2.165	2.19	-0.025	-1.16
67	1.520	1.52	0.000	0.00
68	1.620	1.39	0.230	16.55
69	1.533	1.68	-0.147	-9.59
70	1.732	1.56	0.172	11.03
71	1.540	1.30	0.240	18.47
72	1.552	1.30	0.252	19.39
73	1.420	1.24	0.180	14.52
74	1.652	1.44	0.212	14.73
75	2.258	2.08	0.178	8.56
76	1.621	1.39	0.231	16.62
77	1.641	1.42	0.221	15.57
78	1.494	1.24	0.254	20.48
79	1.592	1.36	0.232	17.06
80	1.550	1.32	0.230	17.42
81	2.125	2.19	-0.065	3.06
82	1.553	1.30	0.253	19.47
83	2.277	2.30	-0.023	-1.01
84	1.496	1.26	0.236	18.33
85	1.812	1.65	0.162	9.82
86	1.493	1.24	0.253	20.40
87	1.502	1.26	0.242	19.21
88	1.493	1.24	0.453	20.41
89	2.120	2.12	0.000	0.00
90	2.170	1.90	0.270	14.21
91	2.293	2.05	0.243	11.86

TABLE 4.10

ACTUAL AND MAXIMUM FEASIBLE YIELDS OF THE SAMPLE PARTICIPANTS GROWING EVs AND LIs IN RABI SEASON

(tons/acre)

Farm No. (1)	MFY (2)	Actual Yield (3)	Difference (2)-(3) (4)	% of Difference (5)
1	1.960	1.78	0.180	10.11
2	1.369	1.18	0.189	16.02
3	1.554	1.30	0.254	19.54
4	2.021	2.15	-0.129	-6.00
5	1.283	1.10	0.183	16.64
6	1.763	1.49	0.273	18.32
7	1.750	1.56	0.190	12.18
8	1.365	1.16	0.205	17.67
9	1.250	1.25	0.000	0.00
10	1.502	1.30	0.202	15.54
11	1.191	0.96	0.231	24.06
12	1.197	1.03	0.167	16.21
13	1.852	1.61	0.242	15.03
14	1.237	0.99	0.247	24.95
15	1.960	2.08	-0.120	-5.77
16	1.430	1.30	0.130	10.00
17	1.666	1.50	0.166	11.07
18	1.461	1.30	0.161	12.38
19	1.395	1.20	0.195	16.25
20	1.359	1.22	0.139	11.39
21	1.560	1.56	0.000	0.00
22	1.618	1.72	-0.102	-5.93
23	1.714	1.56	0.154	9.87
24	1.472	1.30	0.172	13.23
25	2.060	2.06	0.000	0.00
26	1.429	1.30	0.129	9.92
27	1.642	1.50	0.142	9.47
28	1.494	1.40	0.094	6.71
29	1.426	1.27	0.156	12.28
30	1.221	1.04	0.181	17.40
31	1.560	1.56	0.000	0.00
32	1.461	1.40	0.061	4.36
33	2.095	2.03	0.065	3.20
34	1.684	1.40	0.284	20.29
35	1.405	1.30	0.105	8.08
36	1.461	1.30	0.161	12.38
37	1.561	1.54	0.021	1.36
38	2.061	2.02	0.041	2.03
39	1.670	1.56	0.110	7.05
40	2.143	2.08	0.063	3.03

TABLE 4.10 (Cont'd)

41	1.457	1.30	0.157	12.08
42	1.954	1.62	0.334	20.62
43	1.381	1.17	0.211	18.03
44	1.732	1.56	0.172	11.03
45	1.635	1.52	0.115	7.57
46	1.983	1.64	0.343	20.91
47	2.022	2.00	0.022	1.10
48	1.663	1.53	0.133	8.69
49	1.610	1.45	0.160	11.03
50	1.420	1.21	0.210	17.36
51	1.691	1.56	0.131	8.40
52	1.644	1.37	0.274	20.00
53	1.480	1.24	0.240	19.35
54	1.268	1.02	0.248	24.31
55	1.98	2.08	-0.100	-4.81
56	1.732	1.95	-0.218	-11.18
57	1.875	1.78	0.095	5.34
58	1.674	1.60	0.074	4.63
59	1.635	1.50	0.135	9.00
60	1.443	1.30	0.143	11.00
61	2.111	2.01	0.101	5.02
62	1.592	1.56	0.032	2.05
63	2.203	2.08	0.123	5.91
64	1.820	1.82	0.000	0.00
65	1.160	1.00	0.160	16.00
66	2.230	2.40	-0.170	-7.08
67	1.670	1.56	0.110	7.05
68	1.644	1.52	0.124	8.16
69	1.456	1.30	0.156	12.00
70	1.685	1.56	0.125	8.01
71	1.397	1.30	0.097	7.46
72	1.389	1.30	0.089	6.85
73	1.145	1.04	0.105	10.10
74	1.815	1.56	0.255	16.35
75	1.165	1.04	0.125	12.02
76	1.298	1.21	0.088	7.27
77	1.802	1.56	0.242	15.51
78	1.607	1.56	0.047	3.01
79	1.546	1.43	0.116	8.11
80	1.186	1.04	0.146	14.04
81	1.712	1.54	0.172	11.17
82	1.146	1.04	0.106	10.19
83	1.429	1.30	0.129	9.92
84	1.680	1.68	0.000	0.00
85	1.470	1.30	0.170	13.08
86	1.259	1.04	0.219	21.06
87	1.421	1.30	0.121	9.31
88	1.614	1.46	0.154	10.55
89	1.611	1.72	-0.109	-6.34
90	1.591	1.43	0.161	11.26
91	1.642	1.48	0.162	10.95

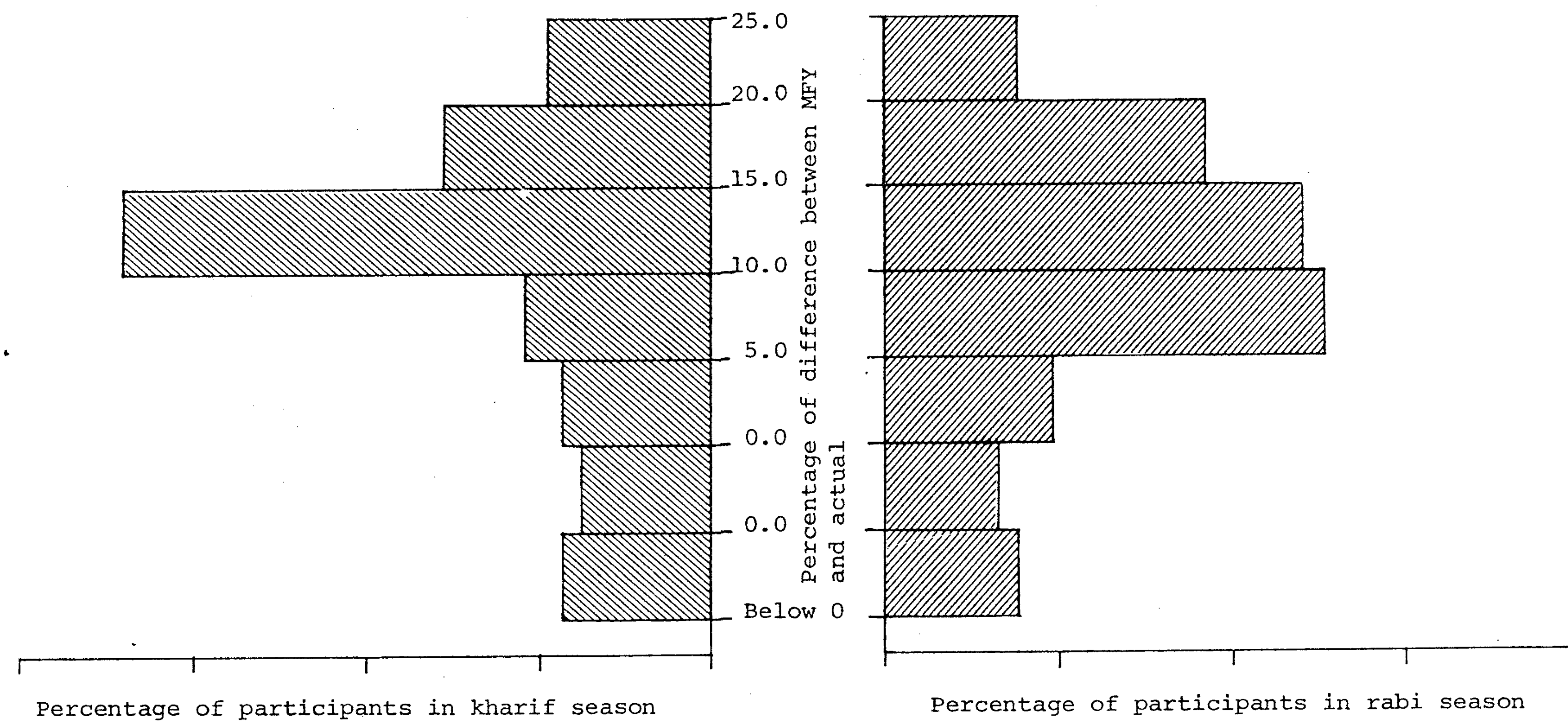


FIGURE 4.2: Percentage differences between MFY and actual yield among participants, by seasons, 1977

influencing the farmer yield gap, attempted below, could help policy-makers to formulate appropriate programmes to help the farmers realise the MFY.[26]

It is assumed here, that knowledge of the technology depends mainly on farmers' experience of growing HYVs, educational level, understanding of recommended cultural practices, keenness to remove their own doubts about the programme, and the number of visits to his farm by extension officials. These factors indirectly relate to the management qualities of farmers and also to their socio-economic characteristics.[27] In this study, an attempt is made to estimate a function of the form:

$$D = \alpha + \sum_{i=1}^{5} \beta_i \quad W_i \tag{4.7}$$

where D refers to the deviation of individual farmer's yield from the MFY (Tables 4.9 and 4.10) and W_i's denote the variables mentioned above.[28] A disturbance term was introduced representing errors in measurements and in observations and deviations of the specified functional form from the true one, along with a dummy variable D_1 differentiating the varieties (D_1 = 1 for LSV or zero otherwise for kharif and D_1 = 1 for EV or zero otherwise for rabi seasons).

The results for kharif season (Table 4.11) show an R^2 of almost 0.64, significant at the 1 per cent level, which means that D in equation

---

26 Logically, if these variables, whose estimates are significant are added to (4.4), then the difference between MFY and actual yield should diminish considerably in kharif, but, because of random factors, may not vanish completely. Since, our aim is to estimate MFY, and to measure the deviation of individual yields from it, the present approach, was selected.

27 It may be remembered in this context that the construction of the variable x_1 (labour) in equation (4.4) and (4.5) attempted to remove the'management bias' to a certain extent.

28 Timmer estimated a similar type of function to explain the difference in technical efficiency indexes with apparent success. [Timmer, C.P. (1970) (pp.152-6).]

TABLE 4.11

ESTIMATED PARAMETERS OF THE FUNCTION EXPLAINING THE DIFFERENCE BETWEEN MFY AND ACTUAL YIELD OF SAMPLE PARTICIPANTS IN KHARIF SEASON

Variable	Parameter
α (constant)	1.6309** (0.7012)
W_1 (experience)	-0.0768*** (0.0523)
W_2 (education)	-0.0731 (0.0806)
W_3 (understanding)	-0.1245** (0.0612)
W_4 (involvement)	0.2035 (0.3123)
W_5 (number of farm visits by extension officials)	-0.0831** (0.0376)
D_1 (varietal dummy)	0.3506 (0.4200)
$\bar{R}^2 = 0.6188$	

Notes: Figures in parentheses are standard errors of estimates.

** significant at the 5 per cent level.

*** significant at the 10 per cent level.

(4.7) is well explained by the independent variables selected. It is interesting to note the significance (5 per cent level) both of the number of extension officials' visits to the participant farms, and the farmers' understanding about the programme. Both showed an inverse relation as might be expected, i.e., an increase in the number of farm visits by extension officials and improved comprehension of the programme decrease the extent of yield variation from MFY. Farm visits by officials enable them to observe the fields at various stages of production. This is important, since with their training, they are able to identify the problems better than the farmers, even in the initial stages. Survey evidence shows that the majority of sample participants did not follow the recommendations for the HYVP closely.[29] The significant estimate of the coefficient of participant understanding about the HYVP, here, implies that there is a possibility of reducing D in equation (4.6), by increasing or improving their understanding of the programme. Our survey showed that in the study area, some of the participants learned about the HYVP from the educated or big landlords. It is quite possible that these landlords who were often approached by extension officials would mix their own views with official recommendations, and in advising other participants, would lead the latter to misunderstand some aspects of the programme.

Other evidence showed that the important and fine detail of the programme was not clearly understood by most of the sample participants. For example, it was recommended that fertiliser

---

29 It should be remembered here that following the recommendations of the HYVP was not a problem for the sample participants. Typically, official recommendations are considered difficult to follow because of the cost of high dosages of fertilisers. But, in the study area almost all used recommended levels or more of fertilisers. Survey farmers would be able to follow other less costly recommendations even more easily.

applications to be made to LSVs and EVs, in two dosages of top-dressing (Table 4.12). In kharif and rabi season, 37 and 41 per cent respectively of sample participants applied all top-dressing requirements in a single dose. They did not understand the importance of proper timing of applications, and why it would make a difference to yield to apply fertilisers 20 days or 40 days after transplanting. In their view, only those who could not afford to buy in bulk, would apply in successive instalments and that the programme was composed this way only for their convenience. Though the Agriculture Department was communicating the recommendations of the HYVP by various means such as slide shows, distribution of leaflets at public gatherings, it appeared that quite a good number of sample participants lacked understanding the importance of correct applications at particular intervals. The estimate of the coefficient of the variable termed 'experience' was significant at the 10 per cent level and was negative, which shows that the greater is the participants' experience in cultivating HYVs, the smaller is the difference between the MFY and actual yield received. This can readily be understood because each year the participant faced different problems in growing HYVs and so in due course learned to understand the ways in which these problems could be reduced. The rest of the coefficients were not statistically significant.

Estimates for rabi seasons (Table 4.13), showed similar results as for kharif season except that R^2 is slightly lower (0.58). The estimates of the coefficients of understanding and extension officials' visits were significant at the 5 per cent level. Together they imply that the difference between the MFY and actual yield of the sample participants in rabi season could be decreased significantly by improving farmers' understanding of the programme and also by increasing extension officials' visits to farmers' fields. The estimate of the coefficient of the variable termed 'experience' was significant at the 10 per cent level only. Other coefficients, namely education and farmer's involvement were not significant statistically. The estimate of the coefficient (D_1) which differentiates the two varieties - EVs and LIs in the function (4.7) was also statistically not significant.

TABLE 4.12

RECOMMENDED DOSES OF FERTILISERS AND THE TIMES OF APPLICATIONS OF TOP-DRESSINGS TO DIFFERENT PADDY VARIETIES IN GOBICHETTIPALAYAM BLOCK

Paddy Variety	Required Fertiliser Application per Acre (Kgs.)							
	Basal			Top-dressings	Total			Time for
	N	P	K	N	N	P	K	Top-dressing
IR20 (EV)	20	20	20	10				20 days after transplanting.
				10				20 days after first application
					40	20	20	
ADT-31 (LSV)	20	20	20	10				20 days after transplanting.
				10				20 days after first application
					40	20	20	
CO-37/ Vaigai (LSV)	15	15	15	7.5				20 days after transplanting.
				7.5				20 days after first application
					30	15	15	
Bhavani (EV)	15	15	15	7.5				20 days after transplanting.
				7.5				20 days after first application
					30	15	15	

Source: Office of the District Agricultural Officer, Gobichettipalayam. Our specifications of the paddy varieties are written within brackets.

TABLE 4.13

ESTIMATED PARAMETERS OF THE FUNCTION EXPLAINING THE DIFFERENCE BETWEEN MFY AND ACTUAL YIELD OF SAMPLE PARTICIPANTS IN RABI SEASON

Variable	Parameter
α (constant)	1.3523** (0.6233)
W_1 (experience)	-0.0595*** (0.0331)
W_2 (education)	-0.0945 (0.1002)
W_3 (understanding)	-0.1095** (0.0507)
W_4 (involvement)	0.2008 (0.2765)
W_5 (number of farm visits by extension officials)	-0.0627** (0.0310)
D_1 (varietal dummy)	0.2878 (0.3102)
$\bar{R}^2 = 0.5552$	

Notes: Figures in parentheses are standard errors of estimates.

** significant at the 5 per cent level.

*** significant at the 10 per cent level.

Conclusions

The results of the previous sections underline the fact that even in an agriculturally advanced district such as Coimbatore, so well endowed with irrigation and institutional facilities and already showing high levels of input usage at farm level, there is scope for major increases in yield levels through varietal breeding programmes that cater specifically for local conditions. The substantial yield improvement of LSVs over the existing EVs in kharif season was obtained partly from the formers' greater inherent yielding capacity, but it also resulted from a reduced susceptibility to BPH, which is the main pest problem in the study area. However, given the continued susceptibility of the current LSVs to BPH attack, it is clear that its characteristic of shorter duration is by no means the final solution. This particular local constraint has been only partially lifted, and scope still remains for further benefits in this direction. However, the reduction of season length with LSVs of shorter duration does lead to considerable saving in irrigation water over at least 20-25 days, which can be used to supplement other needy crops or to extend the area of irrigated paddy. It should be further noted that so far research work has been successful only in evolving LSVs for kharif season. A breakthrough has yet to be accomplished for the rabi season. If success is achieved in rabi, it raises the possibility of converting a two-crop into a three-crop annual cycle of rice growing in Gobichettipalayam block with the existing irrigation water supply.

There were substantial yield differences between farmers in both seasons and for both types of HYVs and were caused, not by problems with conventional inputs, but mainly by factors that reduced technical efficiency.

The analysis showed that these gaps were mainly created by participants' misunderstanding of the programme, or by extension officials' limited contact with the field situation or by both. These factors together explained the major part of the farmer yield gap. Survey data indicated that the number of visits by the extension officials was very low and even nil for some of the sample farms. Information from the District Agriculture Office shows that there were not in fact, enough staff for the extension work of the HYVP.[30] The existing staff, with responsibility also for administration work in the office, has been left with very little time for field extension work. This corroborates the PEO-ANU surveys which drew attention to the problem of staff shortage for the HYVP and recommended to the Indian government that staff at field level should be expanded to improve the performance of the HYVP.[31]

As mentioned earlier, the heavy administrative work load of the extension officials has a negative effect in the performance of the HYVP. This can be explained by the following information available in our survey. Most of the sample participants had not had their soils tested regularly. They complained that after tests they did not receive any result, even after the samples were sent to the laboratory through the Village Local Workers (VLW) or Deputy Agricultural Officers (Dy A.O.). This caused participants to lose interest in the tests. The extension programme should be reoriented to give more emphasis to the amplification of the methods and timing of application of inputs and practices. Field visits by extension

30 PEO-ANU (1977).

31 PEO-ANU (1977) (pp.64-67).

officials should be increased, so that all farmers are benefited. However, this seems not possible without increasing the field staff.

To sum up, it is clear from the above analysis that while the introduction of LSVs has substantially raised the productivity potential of the HYVP in the main paddy growing season, and that their widespread adoption has raised total output in that season, weaknesses still remain in the understanding of the programme by participant farmers. Lack of extension officials could largely explain this problem, and it is therefore, necessary to strengthen and reorganise the extension staff at all levels to improve the performance of the HYVP. Further research should be undertaken to evolve BPH resistant LSVs for kharif season and suitable varieties for rabi season.

CHAPTER 5

ECONOMIC PERFORMANCE OF THE HYVP

The previous chapter showed that physical productivity of irrigated farms could be greatly enhanced with the use of location specific HYVs. It also showed that further gains were possible by improving farmers' understanding of the HYVP, and suggested measures for accomplishing this. However, the success of the evolution of LSVs depends also on their monetary benefits and the distribution of these benefits among participants. The distribution of monetary gains from LSVs is determined not by their adoption alone, but by other aspects of the HYVP such as availability and use of inputs including credit, and participants' ability and willingness to avail themselves of these facilities. Before examining the monetary gains and distributional performance of LSVs, it is necessary to determine the economic impact of LSVs, the result of the interaction between the opportunities provided by the HYVP and the farmers' reaction to these opportunities. Participants' ability and willingness to make use of the opportunities provided by the programme can be examined by analysing their economic behaviour in the cultivation of LSVs and EVs. This behaviour can be seen by examining how efficiently they are cultivating both types of HYVs. For this, participants growing LSVs and EVs in kharif season were each divided into two groups of small and large farmers[1] and their relative economic efficiencies were each tested. The results of these tests for the two groups producing the two varietal types in kharif season were then pooled

1 This division of farms was necessary to enable us to examine the distributional performance of both LSVs and EVs in the light of farm size in the next chapter.

to enable comparisons to be made about the economic behaviour of LSV and EV participants. Similarly, the economic efficiency of EV growers in rabi season was also analysed.

This chapter commences with a brief discussion of input availability and use in the study area. The economic behaviour of participants is then examined in terms of economic efficiency of cultivation, using the profit function and factor demand functions developed in Chapter 3. A final section draws out overall conclusions from the empirical analysis, and possible policy implications within the framework of this study.

Input Availability and Use

There was almost no shortage reported in the supply of inputs in the course of this survey. Nor were there any significant differences between large and small farmers in levels of application of inputs in either season (Tables 5.1 to 5.3).

TABLE 5.1

AVERAGE INPUT APPLICATIONS TO LSVs BY FARM SIZE GROUP, KHARIF SEASON, 1977

Inputs/Farm Characteristics	Average Application per Acre		
	Large Farmers	Small Farmers	T-value
Sample Size	25	25	
Hired Labour (mandays)	190.16	182.36	1.02
Expenditure on Pesticides application (Rs.)	153.56	166.98	1.31
Expenditure on Other Inputs (Rs.)	367.92	300.04	0.59
Nitrogenous Fertiliser (Kgs.)	50.12	47.44	1.42
Phosphatic Fertiliser (Kgs.)	22.48	20.10	1.37
Potassic Fertiliser (Kgs.)	23.88	21.04	1.57
Yield per Acre (tons)	2.33	2.40	0.69

TABLE 5.2

AVERAGE INPUT APPLICATIONS TO EVs BY FARM SIZE GROUP, KHARIF SEASON, 1977

Inputs/Farm Characteristics	Average Application per Acre		
	Large Farmers	Small Farmers	T-value
Hired Labour (mandays)	193.54	187.46	0.51
Expenditure on Pesticides Application (Rs.)	171.94	196.14	0.85
Expenditure on Other Inputs (Rs.)	246.67	277.51	1.59
Nitrogenous Fertiliser (Kgs.)	44.80	46.57	0.60
Phosphorous Fertiliser (Kgs.)	21.10	24.95	1.44
Potassic Fertiliser (Kgs.)	21.05	20.43	0.25
Yield per Acre (tons)	1.57	1.69	0.97

TABLE 5.3

AVERAGE INPUT APPLICATIONS TO EVs BY FARM SIZE GROUP, RABI SEASON, 1977-78

Inputs/Farm Characteristics	Average Application per Acre		
	Large Farmers	Small Farmers	T-value
Hired Labour (mandays)	187.52	189.14	0.36
Expenditure on Pesticides Application (Rs.)	98.54	100.34	0.47
Expenditure on Other Inputs (Rs.)	242.01	217.73	1.10
Nitrogenous Fertiliser (Kgs.)	41.89	41.63	0.18
Phosphorous Fertiliser (Kgs.)	18.57	20.57	1.24
Potassic Fertiliser (Kgs.)	19.03	20.14	0.62
Yield per Acre (tons)	1.48	1.50	0.20

Quality checked seeds were supplied by the agricultural depots and there was no shortage reported by the participants. Private traders also supplemented the supply of seeds in the study area. Some of the participants used seeds grown on their farms, i.e., paddy kept as seed from the previous harvest.

Almost all participants stated that growing HYVs required more labour than was required for local and local improved varieties. Labour availability was not a problem in this area. Labourers used to come regularly and annually from nearby villages in groups to work on farms. Local family labour was not used in field work, hence no farmers reported any increase in the use of family labour in farming operations because of the introduction of HYVs. Though the wage rate per hired labourer (Table 5.4) for various field operations was virtually constant, the mix of field operations varied from farm to farm. For watering, harvesting, threshing and bundling, labourers were usually paid in kind. This was mostly decided as a contract between the employer and a representative of employees. It is worth noting here that there was no labour unrest reported at any time in the survey area in relation to the wages paid to the hired labourers.[2]

The co-operative society serving Seyyampalayam village was actively engaged in the distribution of chemical fertilisers. Besides the co-operative, there were 15 private fertiliser dealers within 10 kilometers of the study area. As a result of these, chemical fertilisers were not in short supply in either survey season. Prices of fertilisers varied a

2 Information supplied by the Block Development Officer, Gobichettipalayam. During the survey, it was also confirmed by the hired labourers working in the sample participants' farms.

TABLE 5.4

AVERAGE DAILY WAGE RATE FOR HIRED LABOUR
IN DIFFERENT FIELD OPERATIONS IN THE STUDY AREA[a]

Field Operation	Daily Wage per Worker (Rs.)		
	Male	Female	Child
Field Preparation	6.00	4.00	2.00
Ploughing	10.00	-	-
Nursery Raising	5.00	3.00	-
Transplanting	5.00	4.00	-
Weeding	5.00	4.00	2.00
Fertilisation	10.00	7.00	-
Pesticide Application	10.00	7.00	-
Watering		(in kind)	
Harvesting		(in kind)	
Threshing and Bundling		(in kind)	

Note: a Paid by sample participants.

little, with location, though prices were fixed by government. Participants applied fertilisers both basal and as top-dressing at rates higher than recommended levels (Tables 5.5 and 5.6) in both seasons. The range of total application of nitrogenous fertiliser was between 40 and 60 kgs. per acre for HYVs in both seasons, as against the recommended 40 kgs. per acre. There were no significant differences in dosages between large and small farmers (Tables 5.1 to 5.3). Thus, fertiliser supply and application levels were not constraints to the HYVP in either season in the study area.

Plant protection chemicals were distributed both by agricultural depots and private dealers. Some chemicals were subsidised by government,

TABLE 5.5

AVERAGE USE OF CHEMICAL FERTILISERS ON HYVs OF PADDY BY THE SAMPLE PARTICIPANTS, THEIR OWN NORMS AND THE OFFICIAL RECOMMENDATIONS BY FIELD OPERATIONS IN KHARIF SEASON, 1977

Fertilisers	Field Operation	Application per Acre (Kgs.)		
		Actual	Own Norm	Recommended
Nitrogen	Basal	23	23	20
Phosphorous	Basal	22	22	20
Potassium	Basal	21	21	20
Nitrogen	Top-dressing	24	24	20
Total		90	90	80

TABLE 5.6

AVERAGE USE OF CHEMICAL FERTILISERS ON HYVs OF PADDY BY THE SAMPLE PARTICIPANTS, THEIR OWN NORMS AND THE OFFICIAL RECOMMENDATIONS BY FIELD OPERATIONS IN RABI SEASON, 1977-78

Fertilisers	Field Operation	Application per Acre (Kgs.)		
		Actual	Own Norm	Recommended
Nitrogen	Basal	22	22	20
Phosphorous	Basal	20	20	20
Potassium	Basal	20	20	20
Nitrogen	Top-dressing	24	24	20
Total		86	86	80

and were supplied to farmers through a system of identification cards[3] issued by the Plant Protection Officer (a Deputy Agricultural Officer) in the block. The sample participants reported that the supply of plant protection chemicals was adequate and also was timely (see the Qualitative Schedule in Appendix 2.3). Only 5 per cent of sample farmers owned pesticide sprayers: the rest hired them either from the Panchayat Union Office or from individual agencies. The Plant Protection Officer claimed that the supply of sprayers hired out was adequate to meet the demand of the participants. Prices of plant protection chemicals varied with location and popularity, and there were no government fixed prices for these chemicals.

Sample participants indicated that credit was not a problem (Appendix 2.3). There were four main sources in the study area: co-operative society, commercial banks, money-lenders, and relatives and friends. Almost 50 per cent of sample farmers obtained credit from their relatives and friends and in most cases without interest charges. In their view, credit in cash or kind received from any of the first three sources was a loan, but was not when it was from relatives and friends. Surprisingly, the services of the co-operative society in advancing loans (Table 5.7) was considered satisfactory by a majority of participants.[4] Co-operative credit was sufficient and timely, as reported by the sample participants. Only 5 per cent of the sample complained of inadequacy of

---

3 A card gave information of farmer's name, address, area operated and special problems of pests and diseases, if any.

4 Generally, it is said that the co-operative credit is not adequate and also not functioning efficiently, favouring only large farmers; its supply is not timely. [See Shand, R.T. (1978).] In the study area the number of defaulters in each year was very small and was one of the reasons for the efficient functioning of the co-operative society.

TABLE 5.7

CHARACTERISTICS OF THE CO-OPERATIVE SOCIETY, SERVING THE STUDY AREA

Area covered (villages)	Lakkampatti, Seyyampalayam and Ayalur		
Total population served:	18,608	All Villages	Seyyampalayam
Members:	big farmers:	918	81
	small farmers:	1,838	102
	non-agriculturalists:	890	93
	Total	3,646	276
Eligibility for receiving loan:	Possession of minimum ½ acre owned or leased in land		
Amount given as loan: (per acre)	Paddy:	Rs.400	
	Sugar Cane:	Rs.1,200	
	Turmeric:	Rs.1,400	
Maximum loan limit for an individual (per acre)		Rs.15,000	
Number of loans sanctioned during 1976-77:		All Villages	Seyyampalayam
	big farmers:	611	74
	small farmers:	638	93

loans for small farmers from the nationalised commercial banks. However, their needs were met by other sources of lending. Thus, availability of credit was not a constraint for the sample participants in the HYVP.

In short, there was easy and equal access for almost all farmers in the study area to all important inputs, regardless of farm size. The non-significance of differences between small and large farmers in levels of inputs applied and yields obtained implies that sample participants made good use of the opportunities provided by this largely equal access to inputs within the HYVP. Thus evidence showed that there were no constraints in the study area on input availability and use.

Both small and large farmers had equal marketing access for their paddy output. Price prospects were consistently favourable as the district was in deficit for foodgrain. The sample participants' expectations of market price for paddy more or less coincided with the actual price they received, during the year under study as reported by them in the Qualitative Schedule (Appendix 2.3). Virtually nobody stored the harvest beyond a month after harvest in anticipation of higher price for later sale.[5] Within this framework, we examine below, the way in which sample farmers availed themselves of these opportunities provided.

Economic Efficiency

The most important standard of judgement of decision-making in the production process is that of economic efficiency. This comprises two important components, namely, the farmer's ability and wish to obtain the greatest possible output from a given set of inputs and to maximise profits, by equating marginal revenue product of factors of production with their marginal cost. The latter component of economic efficiency is known as price or allocative efficiency while the former is called technical efficiency.[6] Theoretically, farms can be expected to produce identical outputs with identical inputs provided they all had the same

---

5 They did not store because they received their anticipated prices immediately after harvest. The rabi season started immediately after harvest of the kharif season for which they needed money to carry on field operations.

6 Yotopoulos, P.A. and J.B. Nugent (1976) (pp.71-85).

production function, the same input and output prices, and they all attempted to maximise profits. In practice, it is found that farms produce the same output with varying factor intensities because, even assuming they want to maximise profits, they face different prices for homogeneous inputs and output, and they have different fixed factors of production such as technical knowledge and land, and socio-economic environment.[7] These differences in prices and fixed non-conventional factors of production give rise to varying degrees of price and technical efficiencies respectively which thus produce differences in overall economic efficiency among farms. Measures of economic efficiency should therefore take account of the possibility of different prices for homogeneous products for the farmers and varying fixed factors of production among farms.

Simple measures of economic efficiency are returns to a single factor of production, like labour, capital, and land, where all other factors are valued at their market prices.[8] The assumption that the market price of a factor is the same for all producers, is not, however, valid in practice. Also, this approach does not specify any optimum level of production, and so vitiates comparisons of these measures. Conventional production function analysis assumes implicitly that technical efficiency is the same[9] for all farms being compared, and further, it does not incorporate prices as exogenous variables nor allows for imperfect maximisation. The profit function allows for farms paying different prices for homogeneous variable factors of production and for farms having varying

---

7 Ibid. (pp.87-8).

8 They are called partial measures of efficiency in the literature.

9 This drawback can be overcome by estimating a frontier production function rather than the average production function, as done in Chapter 4 above. The technical efficiency was measured in terms of deviations of individual farm yields from a frontier (MFY) function.

quantities of fixed factors of production.[10] It allows for interfarm differences in equating the marginal value product of variable inputs with their prices. Thus, the profit function describes economic efficiency adequately, incorporating its two components of technical and price efficiency.[11]

For the purpose of examining the relative economic efficiency of the small and the large farm group, group-specific technical efficiency and input-specific, also group-specific price efficiency are explicitly introduced into the farms' profit functions, as discussed in Chapter 3 above. The two groups are called equally efficient economically, when they both produce maximum output with given inputs and both equate the marginal value product of variable factors of production with their marginal costs to the same degree. Relative economic efficiency in the context of Cobb-Douglas production and unit output price profit functions is judged below by testing whether the UOP profit functions of the two groups (small and large farmers) differ from one another significantly, i.e., by examining whether $A_*^1 = A_*^2$ in equation (3.46). This could happen only if $A^1 = A^2$ and $k^1 = k^2$ in the profit functions (3.45). Since identification of causes of differences in economic efficiency among groups of farms is important for policy formulation, it becomes necessary to test separately the hypothesis of equal relative technical and price efficiencies.[12] This is undertaken in the following sections, for small and large farm groups by varieties and seasons.

---

10 They are discussed in detail in Chapter 3 above.

11 Yotopoulos, P.A. (1974) 'Rationality, efficiency, and organisational behaviour through the production function, darkly', Food Research Institute Studies, Vol.13, No.3, (pp.263-74).

12 It is assumed that there is no non-neutral shift between the production functions of small and large farm groups.

Relative Efficiency:

The UOP profit and factor demand functions used in this section are rewritten from (3.50) and (3.51) above.

$$\ln \pi = \lambda + \alpha_0^* D_1 + \beta_1^* \ln W + \beta_2^* \ln F + \beta_3^* \ln P + \beta_4 \ln B + \alpha_1^* \ln L + \alpha_2^* \ln C \qquad (5.1)$$

Factor demand functions for labour fertiliser, pesticides and animal power are:

$$\begin{aligned} -\frac{Wx_1}{\pi} &= \beta_1^{*S} D_1 + \beta_1^{*L} D_2 \\ -\frac{Fx_2}{\pi} &= \beta_2^{*S} D_1 + \beta_2^{*L} D_2 \\ -\frac{Px_3}{\pi} &= \beta_3^{*S} D_1 + \beta_3^{*L} D_2 \\ -\frac{Bx_4}{\pi} &\quad \beta_4^{*S} D_1 + \beta_4^{*L} D_2 \end{aligned} \qquad (5.2)$$

The estimated parameters, using Aitken's restricted least squares method, for both LSVs and EVs in the kharif season, and for EVs in the rabi season, are presented in Tables 5.8 to 5.10 respectively.

Equal Relative Economic Efficiency: Given equal access to inputs and technology, the two participant groups were expected to have equal relative economic efficiency. The hypothesis of equal relative economic efficiency of small and large farm groups growing LSVs in kharif is tested and can be represented as:

$$H_0 \quad : \quad \alpha_0 = 0 \qquad (5.2)$$

This hypothesis means that $\ln A_*^2 - \ln A_*^1 = 0$ or $A_*^1 = A_*^2$. This implies

TABLE 5.8

JOINT ESTIMATION OF NORMALISED PROFIT FUNCTION AND VARIABLE FACTOR DEMAND FUNCTIONS - LSV GROWERS IN KHARIF SEASON

Variable	Parameter	Estimated Values				
		OLS	GLS	Restricted GLS		
				Restriction I	Restriction II	Restriction III
(1)	(2)	(3)	(4)	(5)	(6)	(7)
Profit function:						
Constant	$\ln A_*$	7.4775^{**} (1.5881)	7.3946^{**} (1.3509)	6.9365^{**} (1.3507)	6.8003^{**} (1.3102)	6.6906^{**} (1.3215)
ln W	β_1^*	-0.7330^{**} (0.2415)	-0.7185^{**} (0.2756)	-0.7116^{**} (0.2755)	-0.4583^{**} (0.1149)	-0.4566^{**} (0.1148)
ln F	β_2^*	-1.6169^{**} (0.5076)	-1.6220^{**} (0.4332)	-1.6458^{**} (0.4331)	-0.7335^{**} (0.1971)	-0.7408^{**} (0.1961)
ln P	β_3^*	-0.0901^{**} (0.0203)	-0.0645^{**} (0.0220)	-0.0611^{**} (0.0230)	-0.0613^{**} (0.0278)	-0.0605^{**} (0.0275)
ln B	β_4^*	-0.0843^{***} (0.0425)	-0.0676^{***} (0.0359)	-0.0686^{**} (0.0320)	-0.0667^{**} (0.0303)	-0.0691^{**} (0.0236)
ln L	α_1^*	0.9913^{*} (0.1379)	0.9635^{*} (0.1169)	0.9617^{*} (0.1172)	0.93006^{**} (0.1132)	0.9714^{**} (0.1208)
ln C	α_2^*	0.0512^{**} (0.0216)	0.0405^{**} (0.0185)	0.0412^{**} (0.0183)	0.0604^{**} (0.0263)	0.0286^{***} (0.0178)
D_1	α_0	-0.0639 (0.2077)	0.0376 (0.1959)	0.0445 (0.1758)	0.1537 (0.1737)	0.1043 (0.1182)
Labour demand fn.	β_1^{*S}	-0.6876^{**} (0.2338)	-0.6438^{**} (0.2125)	-0.4810^{**} (0.1202)	-0.4583^{**} (0.1149)	-0.4566^{**} (0.1148)
	β_1^{*L}	-0.5727^{***} (0.3420)	-0.5910^{**} (0.2236)	-0.4810^{**} (0.1202)	-0.4583^{**} (0.1149)	-0.4566^{**} (0.1148)

TABLE 5.8 (Cont'd)

Fertiliser demand fn.	β_2^{*S}	-1.4102^{**}	-1.6710^{**}	-1.2268^{**}	-0.7335^{**}	-0.7408^{**}
		(0.5027)	(0.4910)	(0.4294)	(0.1971)	(0.1961)
	β_2^{*L}	-0.0600^{**}	-0.0523^{**}	-0.0461^{**}	-0.0613^{**}	-0.0605^{**}
		(0.0248)	(0.0228)	(0.0228)	(0.0278)	(0.0275)
Animal power demand fn.	β_4^{*S}	-0.0720^{**}	-0.0710^{**}	-0.0510^{***}	-0.0667^{**}	-0.0691^{**}
		(0.0279)	(0.0268)	(0.0262)	(0.0303)	(0.0236)
	β_4^{*L}	-0.0810^{**}	-0.0624^{**}	-0.0510^{***}	-0.0667^{**}	-0.0691^{**}
		(0.0375)	(0.0310)	(0.0262)	(0.0303)	(0.0236)

Notes: Figures in parentheses are standard errors of estimates.

* significant at the 1 per cent level.

** significant at the 5 per cent level.

*** significant at the 10 per cent level.

Restriction I : $\beta_s^{*S} = \beta_2^{*L}$ $\quad s = 1,2,3,4.$

Restriction II : $\beta_s^{*S} = \beta_s^{*}$ and $\beta_s^{*S} = \beta_s^{*L}$

Restriction III: $\beta_s^{*S} = \beta_s^{*L}$

$\beta_s^{*S} = \beta_s^{*}$; $\beta_s^{*L} = \beta_s^{*}$; and $\alpha_1^{*} + \alpha_2^{*} = 1$

TABLE 5.9

JOINTLY ESTIMATED PARAMETERS OF NORMALISED PROFIT FUNCTION
AND VARIABLE FACTOR SHARE FUNCTIONS - EV GROWERS IN KHARIF SEASON

Variable	Parameter	Estimated Values: OLS	GLS	Restricted GLS: Restriction I	Restriction II	Restriction III
(1)	(2)	(3)	(4)	(5)	(6)	(7)
Profit function:						
Constant	$\ln A_*$	7.0300**	7.0009**	6.9153**	6.5316**	6.3100**
		(1.9326)	(1.6010)	(1.5039)	(1.3723)	(1.2879)
ln W	β_1^*	-0.6982**	-0.5666**	-0.5814**	-0.5715***	-0.5619**
		(0.3197)	(0.2612)	(0.2503)	(0.2901)	(0.2491)
ln F	β_2^*	-2.0009**	-2.0487**	-1.8681**	-1.2019***	-0.8253**
		(0.5476)	(0.5720)	(0.4620)	(0.6290)	(0.3550)
ln P	β_3^*	-0.0728	-0.0680***	-0.0637**	-0.0672	-0.0689
		(0.0489)	(0.0403)	(0.0281)	(0.0491)	(0.0493)
ln B	β_4^*	-0.1131	-0.1077***	-0.1093**	-0.1210	-0.0703**
		(0.0719)	(0.0589)	(0.0522)	(0.08862)	(0.0340)
ln L	α_1^*	0.9841*	0.9565*	0.9452*	0.9518*	0.9618*
		(0.1551)	(0.1478)	(0.1376)	(0.1462)	(0.1412)
ln C	α_2^*	0.0652**	0.0596**	0.0499**	0.0501**	0.0392**
		(0.0235)	(0.0210)	(0.0202)	(0.0235)	(0.0193)
D_1	α_0	-0.2653	-0.2441	0.1710	-0.0478	-0.0335
		(0.3412)	(0.3108)	(0.2602)	(0.1938)	(0.1567)
Labour share fn.	β_1^{*S}	-0.5655**	-0.5928**	-0.6485**	-0.5715***	-0.5619**
		(0.2273)	(0.2109)	(0.2031)	(0.2901)	(0.2491)
	β_1^{*L}	-0.4152**	-0.4277**	-0.6485**	-0.5715***	-0.5619**
		(0.1982)	(0.1708)	(0.2031)	(0.2901)	(0.2491)

TABLE 5.9 (Cont'd)

Fertiliser share fn.	β_2^{*S}	-0.8731^{**} (0.3436)	-0.6899^{**} (0.3007)	-1.6001^{**} (0.4167)	-1.2019^{**} (0.6290)	-0.8253^{**} (0.3550)
	β_2^{*L}	-0.7239^{**} (0.3391)	-0.6621^{**} (0.2998)	-1.6001^{**} (0.4167)	-1.2019^{***} (0.6190)	-0.8253^{**} (0.3550)
Pesticides share fn.	β_3^{*S}	-0.0715 (0.0462)	-0.0752^{***} (0.0387)	-0.0856^{**} (0.0337)	-0.0672 (0.0491)	-0.0629^{**} (0.0203)
	β_3^{*L}	-0.0681^{***} (0.0377)	-0.0589^{***} (0.0293)	-0.0856^{**} (0.0337)	-0.0672 (0.0491)	-0.0629^{**} (0.0203)
Animal power share fn.	β_4^{*S}	-0.1048 (0.0621)	-0.1121^{***} (0.0570)	-0.1065^{**} (0.0510)	-0.1210 (0.0862)	-0.0703^{**} (0.0340)
	β_4^{*L}	-0.0948 (0.0591)	-0.1092^{**} (0.0523)	-0.1065^{**} (0.0510)	-0.1210 (0.0862)	-0.0703^{**} (0.0340)

<u>Notes:</u> Figures in parentheses are standard errors of estimates.

* significant at the 1 per cent level.

** significant at the 5 per cent level.

*** significant at the 10 per cent level.

Restriction I : $\beta_s^{*S} = \beta_s^{*L}$ $s = 1,2,3,4.$

Restriction II : $\beta_s^{*L} = \beta_s^{*}$ and $\beta_s^{*S} = \beta_s^{*L}$

Restriction III: $\beta_s^{*S} = \beta_s^{*}$, $\beta_s^{*L} = \beta_s^{*}$ $s = 1,2,4.$

$\beta_s^{*S} = \beta_s^{*L}$ $s = 1,2,3,4$; and

$\alpha_1^{*} + \alpha_2^{*} = 1$

TABLE 5.10

JOINTLY ESTIMATED PARAMETERS OF NORMALISED PROFIT FUNCTION AND VARIABLE FACTOR SHARE FUNCTIONS - EV GROWERS IN RABI SEASON

Variable	Parameter	Estimated Values				
		OLS	GLS	Restricted GLS		
				Restriction I	Restriction II	Restriction III
(1)	(2)	(3)	(4)	(5)	(6)	(7)
Profit function:						
Constant	$\ln A_*$	6.3210^{**}	6.3019^{**}	6.003^{**}	5.7432^{**}	5.6531^{**}
		(0.1602)	(0.1573)	(0.1432)	(0.1356)	(0.1260)
ln W	β_1^*	-0.6769^{**}	-0.6362^{**}	-0.5917^{**}	-0.5820^{**}	-0.5325^{**}
		(0.1935)	(0.1872)	(0.1803)	(0.1935)	(0.1793)
ln F	β_2^*	-1.8087^{**}	-1.7264^{**}	-1.2079^{**}	-0.9100^{***}	-0.8626^{**}
		(0.4551)	(0.4100)	(0.3560)	(0.4605)	(0.3209)
ln P	β_3^*	-0.1026^{**}	-0.1101^{**}	-0.0852^{**}	-0.0603	-0.0847
		(0.0432)	(0.0400)	(0.0325)	(0.0425)	(0.0499)
ln B	β_4^*	-0.1739^{**}	-0.1602^{**}	-0.1320^{**}	-0.1108^{***}	-0.1006^{**}
		(0.0510)	(0.0473)	(0.0390)	(0.0564)	(0.0304)
ln L	α_1^*	0.9325^{*}	0.9543^{*}	0.9724^{*}	0.9756^{*}	0.9802^{*}
		(0.1610)	(0.1572)	(0.1460)	(0.1520)	(0.1407)
ln C	α_2^*	0.0469^{**}	0.0350^{***}	0.0210^{**}	0.0320^{**}	0.0198^{**}
		(0.0200)	(0.0192)	(0.0103)	(0.0143)	(0.0093)
D_1	α_0	0.2069	0.1863	0.1752	0.1695	0.1532
		(0.3247)	(0.2762)	(0.2349)	(0.1802)	(0.1903)
Labour share fn.	β_1^{*S}	-0.5224^{**}	-0.5117^{**}	-0.6210^{**}	-0.5820^{**}	-0.5325^{**}
		(0.2221)	(0.2107)	(0.2004)	(0.1935)	(0.1793)
	β_1^{*L}	-0.6198^{**}	-0.5782^{**}	-0.6210^{**}	-0.5820^{**}	-0.5325^{**}
		(0.1484)	(0.1372)	(0.2004)	(0.1935)	(0.1793)

TABLE 5.10 (Cont'd)

Fertiliser share fn.	β_2^{*S}	-1.2218^{**}	-1.2109^{**}	-0.9872^{**}	-0.9100^{***}	-0.8626^{**}
		(0.2926)	(0.2523)	(0.1298)	(0.4605)	(0.3209)
	β_2^{*L}	-0.9895^{**}	-0.9912^{**}	-0.9872^{**}	-0.9100^{***}	-0.8626^{**}
		(0.2054)	(0.2036)	(0.1298)	(0.4605)	(0.3209)
Pesticides share fn.	β_3^{*S}	-0.1370^{**}	-0.1304^{**}	-0.0863^{**}	-0.0603	-0.0796^{**}
		(0.0620)	(0.0598)	(0.0410)	(0.0425)	(0.0309)
	β_3^{*L}	-0.1145^{**}	-0.1097^{**}	-0.0863^{**}	-0.0603	-0.0796^{**}
		(0.0403)	(0.0364)	(0.0410)	(0.0425)	(0.0309)
Animal power share fn.	β_4^{*S}	-0.1379^{**}	-0.1402^{**}	-0.1209^{**}	-0.1108^{**}	-0.1006^{**}
		(0.0419)	(0.0400)	(0.0352)	(0.0564)	(0.0304)
	β_4^{*L}	-0.2079^{**}	-0.1903^{**}	-0.1209^{**}	-0.1108^{***}	-0.1006^{**}
		(0.0756)	(0.0678)	(0.0352)	(0.0564)	(0.0304)

Notes: Figures in parentheses are standard errors of estimates.

* significant at the 1 per cent level.

** significant at the 5 per cent level.

*** significant at the 10 per cent level.

Restriction I : $\beta_s^{*S} = \beta_s^{*L}$ $s = 1,2,3,4.$

Restriction II : $\beta_s^{*L} = \beta_s^{*}$ and $\beta_s^{*S} = \beta_s^{*L}$

Restriction III: $\beta_s^{*S} = \beta_s^{*}$ $s = 1,2,4.$

$\beta_s^{*L} = \beta_s^{*}$ $s = 1,2,4.$

$\beta_s^{*S} = \beta_s^{*L}$ $s = 1,2,3,4.$; and $\alpha_1^{*} + \alpha_2^{*} = 1$

that $A^1 = A^2$ and $k^1 = k^2$ and the profit functions and variable factor demand functions of both small and large farm groups coincide. Table 5.8 shows that the null hypothesis of equal relative economic efficiency cannot be rejected at the 90 per cent level of significance, which suggests that the small and large farmer groups showed equal overall economic efficiency in cultivating LSVs. Table 5.9 shows, since the coefficient of D_1 was not statistically different from zero at the 90 per cent level of significance, that there was equal relative economic efficiency in the cultivation of EVs in kharif season among small and large farmers. Table 5.10 similarly shows that there was equal relative economic efficiency among small and large cultivator groups of EVs in rabi season.[13]

The next objective is to determine whether small and large farm groups have equal relative price and technical efficiencies. This is attempted with the hypotheses:

a. Small and large farmer groups are equally price efficient; and

b. small and large farmer groups are equally price and economically efficient.

Equal relative price efficiency can be tested with the following hypothesis:

$$H_0 \quad : \quad \beta_i^{*S} = \beta_i^{*L} \qquad i = 1,2,3,4 \tag{5.3}$$

This test shows whether the demand functions for labour, fertiliser, pesticides and animal power for small and large farmer groups have the same

13 Note that the sample size and the sample participants were not the same for EV growers in kharif and rabi.

efficiency parameters. The equality of parameters need not necessarily indicate perfect maximisation, but it does indicate that both groups succeeded to the same degree in maximising profits.

Our analysis showed that the null hypothesis of equal relative price efficiency of small and large farmer groups growing LSVs in kharif cannot be rejected at the 10 per cent level because the estimates of λ did not significantly differ from zero and the value of χ^2 was not significant, which indicates that the restrictions were satisfied and that there were no differences between price efficiency parameters of small and large farm groups (Table 5.11). This means that both groups were successful to the same degree in maximising profits. The results of Tables 5.12 and 5.13 similarly show that both small and large cultivator groups of EVs, either in kharif or rabi seasons, succeeded to the same degree in maximising profits.

Equal relative technical efficiency can be tested, by testing the hypotheses jointly, of equal relative economic and price efficiencies. The null hypothesis of equal relative technical efficiency between the small and large farm groups was tested by examining the following joint hypotheses:

$$H_0 \quad : \quad \alpha_0 = 0 \quad \text{and} \quad \beta_i^{*S} = \beta_i^{*L} \qquad i = 1,2,3,4 \tag{5.4}$$

Acceptance of the joint hypothesis means that small and large farm groups are equally efficient economically and are price efficient. This further implies that both farm groups are equally efficient technically. The analysis showed:

a. The two farm size groups were equally efficient economically and were equally price efficient

TABLE 5.11

RESULTS OF STATISTICAL TESTS OF HYPOTHESES COMPARING SMALL AND LARGE FARMERS GROWING LSVs IN KHARIF SEASON

Restrictions Used	Lagrange Multiplier	χ^2-value showing the validity of restrictions taken together
$\beta_1^{*S} = \beta_1^{*L}$	1.3529 (1.3002)	
$\beta_2^{*S} = \beta_2^{*L}$	0.3779 (1.2240)	6.1920
$\beta_3^{*S} = \beta_3^{*L}$	1.2480 (1.6048)	
$\beta_4^{*S} = \beta_4^{*2}$	1.4377 (1.0216)	
$\beta_1^{*S} = \beta_1^{*}$	1.6659 (1.3485)	
$\beta_2^{*S} = \beta_2^{*}$	1.2047 (1.3857)	7.1082
$\beta_3^{*S} = \beta_3^{*}$	1.9275 (1.5346)	
$\beta_4^{*S} = \beta_4^{*}$	1.8695 (1.7902)	
$\beta_1^{*L} = \beta_1^{*}$	1.6409 (1.3492)	
$\beta_2^{*L} = \beta_2^{*}$	1.2712 (1.3926)	7.2407
$\beta_3^{*L} = \beta_3^{*}$	2.0593 (2.5433)	
$\beta_4^{*L} = \beta_4^{*}$	1.9607 (1.8254)	

TABLE 5.11 (Cont'd)

$\beta_1^{*S} = \beta_1^*$	1.6559 (1.3472)	13.4333
$\beta_2^{*S} = \beta_2^*$	1.2352 (1.3809)	
$\beta_3^{*S} = \beta_3^*$	1.8268 (1.7001)	
$\beta_4^{*S} = \beta_4^*$	1.8001 (1.3956)	
$\beta_1^{*L} = \beta_1^*$	1.6559 (1.3472)	
$\beta_2^{*L} = \beta_2^*$	1.2352 (1.3809)	
$\beta_3^{*L} = \beta_3^*$	1.8268 (1.7001)	
$\beta_4^{*L} = \beta_4^*$	1.8001 (1.3956)	
$\alpha_1^* + \alpha_2^*$	0.6331 (0.8627)	

Notes: Figures in parentheses are standard errors of estimates.

Critical F-ratio is $F_{0.10}(1,120) = 2.75$;

Critical χ^2-values: $\chi^2_{0.10(4)} = 7.78$

$\chi^2_{0.10(9)} = 14.68$

in cultivating LSVs in kharif season, as the value of χ^2 was not significant at the 5 per cent level (Table 5.11). This means that both farm groups were relatively equally efficient technically with LSVs.

b. In kharif and rabi seasons, both groups were equally efficient economically and were equally price efficient in the production of EVs, as χ^2 in both tests were not significant at the 5 per cent level (Tables 5.12 and 5.13). This implies that both small and large farm groups were equally efficient technically with EVs.

Absolute Price Efficiency:

The equality of the price efficiency parameters in the profit functions of small and large farm groups is a necessary condition in statistical testing of profit maximisation. The necessary and sufficient condition for profit maximisation, otherwise called the condition for perfect profit maximisation, is that a farm or farm group has maximised profits subject to given (market) prices.[14] Thus, perfect profit maximisation for the sample farm group implies:[15]

$$k_s^i = 1 \qquad s = 1,2,3,4 \quad i = 1,2 \tag{5.5}$$

---

14 Yotopoulos, P.A. and L.J. Lau (1973) (pp.217-8).

15 In (3.42), it was assumed that k_j^i represented differences in equating the marginal value product and cost of the variable factors of production. This difference could happen because of: (i) consistent over- or under-valuation of the opportunity costs of factors by the farm; (ii) divergence of expected and normalised price; and (iii) satisficing behaviour of the farm. [Ibid., (p.215).]

TABLE 5.12

RESULTS OF STATISTICAL TESTS OF HYPOTHESES COMPARING SMALL AND LARGE FARMS GROWING EVs IN KHARIF SEASON

Restrictions Used	Lagrange Multiplier	χ^2-value showing the validity of restrictions taken together
$\beta_1^{*S} = \beta_1^{*L}$	0.2039 (0.6144)	
$\beta_2^{*S} = \beta_2^{*L}$	1.6035 (1.4062)	6.1625
$\beta_3^{*S} = \beta_3^{*L}$	0.6852 (0.4850)	
$\beta_4^{*S} = \beta_4^{*L}$	0.4179 (0.6524)	
$\beta_1^{*S} = \beta_1^{*}$	0.4638 (0.3437)	
$\beta_2^{*S} = \beta_2^{*}$	1.7783 (1.4750)	10.8234**
$\beta_3^{*S} = \beta_3^{*}$	4.1499** (0.8653)	
$\beta_4^{*S} = \beta_4^{*}$	0.3543 (0.4786)	
$\beta_1^{*L} = \beta_1^{*}$	0.3872 (0.3561)	
$\beta_2^{*L} = \beta_2^{*}$	1.7308 (1.5100)	12.1237**
$\beta_3^{*L} = \beta_3^{*}$	4.3210** (0.9001)	
$\beta_4^{*L} = \beta_4^{*}$	0.3723 (0.4803)	

TABLE 5.12 (Cont'd)

$\beta_1^{*S} = \beta_1^*$	0.2572 (0.5200)	6.1398
$\beta_2^{*S} = \beta_2^*$	1.6531 (1.4875)	
$\beta_3^{*S} = \beta_3^*$	0.7120 (0.5390)	
$\beta_1^{*L} = \beta_1^*$	0.2572 (0.5200)	
$\beta_2^{*L} = \beta_2^*$	1.6531 (1.4875)	
$\beta_3^{*L} = \beta_3^*$	0.7120 (0.5390)	
$\beta_4^{*S} = \beta_4^{*L}$	0.4325 (0.5879)	
$\alpha_1^* + \alpha_2^* = 1$	0.1154 (0.5740)	

Notes: Figures in parentheses are standard errors of estimates.

** significant at the 5 per cent level.

Critical χ^2 values: $\chi^2_{0.10(4)} = 7.78$

$\chi^2_{0.05(4)} = 9.49$

$\chi^2_{0.10(5)} = 9.24$

TABLE 5.13

RESULTS OF STATISTICAL TESTS OF HYPOTHESES COMPARING SMALL AND LARGE FARMERS GROWING EVs IN RABI SEASON

Restrictions Used	Lagrange Multiplier	χ^2-value showing the validity of restrictions taken together
$\beta_1^{*S} = \beta_1^{*L}$	0.9069 (1.0547)	6.7682
$\beta_2^{*S} = \beta_2^{*L}$	0.8426 (1.0228)	
$\beta_3^{*S} = \beta_3^{*L}$	1.6631 (1.3160)	
$\beta_4^{*S} = \beta_4^{*L}$	0.2281 (0.4898)	
$\beta_1^{*S} = \beta_1^{*}$	1.0375 (1.5623)	10.8234**
$\beta_2^{*S} = \beta_2^{*}$	1.0730 (1.0820)	
$\beta_3^{*S} = \beta_3^{*}$	3.9689** (1.3204)	
$\beta_4^{*S} = \beta_4^{*}$	0.3009 (0.5206)	
$\beta_1^{*L} = \beta_1^{*}$	0.9872 (1.3208)	10.1656**
$\beta_2^{*L} = \beta_2^{*}$	0.9685 (1.0035)	
$\beta_3^{*L} = \beta_3^{*}$	4.0265** (1.5360)	
β_4^{*L} β_4^{*}	0.2579 (0.4311)	

TABLE 5.13 (Cont'd)

$\beta_1^{*S} = \beta_1^*$	0.9235 (0.9872)	6.0375
$\beta_2^{*S} = \beta_2^*$	0.8318 (1.0032)	
$\beta_3^{*S} = \beta_3^*$	1.7208 (1.5003)	
$\beta_1^{*L} = \beta_1^*$	0.9235 (0.9872)	
$\beta_2^{*L} = \beta_2^*$	0.8318 (1.0032)	
$\beta_3^{*L} = \beta_3^*$	1.7208 (1.5003)	
$\beta_4^{*S} = \beta_4^{*L}$	0.2372 (0.4600)	
$\alpha_1^* + \alpha_2^* = 1$	0.3106 (0.6211)	

Notes: Figures in parentheses are standard errors of estimates.

** significant at the 5 per cent level.

Critical χ^2 values: $\chi^2_{0.10(4)} = 7.78$

$\chi^2_{0.05(4)} = 9.49$

$\chi^2_{0.10(5)} = 9.24$

and $k_*^i = 1$

Because of (3.47) it follows that:

$$\beta^{*i} = \beta_s^* \qquad s = 1,2,\ldots m \tag{5.6}$$

Thus, the hypothesis,

$$H_0 \quad : \quad \beta_s^{*S} = \beta_s^* \qquad s = 1,2,3,4 \tag{5.7}$$

is equivalent to testing the null hypothesis of absolute price efficiency of the small farm group, maintaining the hypothesis of (5.3). Similarly, the hypothesis,

$$H_0 \quad : \quad \beta_s^{*L} = \beta_s^* \qquad s = 1,2,3,4 \tag{5.8}$$

means testing the absolute price efficiency of the large farm group, also maintaining (5.3).

Absolute Price Efficiency of the Small Farm Group: The results of tests of absolute price efficiency of the small farm group engaged in LSV production (Table 5.11) show that the null hypothesis of (5.7) cannot be rejected at the 10 per cent level, which indicates that LSV growers in the small farm group in kharif season did maximise profits given the market prices, since the efficiency parameter $k_s^S = 1$ for all $s = 1,2,3,4$. In contrast, the analysis of the small farm group growing EVs in kharif season, 1977 (Table 5.12) showed that the χ^2 was significant at the 5 per cent level, which means that the null hypothesis can be rejected at the 95 per cent level of confidence. This implies that the small farm group growing EVs in kharif season did not perfectly maximise its profits in relation to the levels of the utilisation of the variable factors of production. The group was thus not using variable factors of production at an optimum level. Our approach of estimation[16] enables us to find out, under certain assumptions, which of the factors were not used at optimum levels. Assuming that all restrictions using the hypothesis (3.7) were correct, the estimate of λ for the equality of the price efficiency parameter with respect to pesticides estimated from the factor demand function and profit function was significant at the 5 per cent level (Table 5.12). The significance of λ in relation to pesticides means that for pesticide use, the small farm group was not able to equate the marginal value product and marginal cost.[17] Similar results were obtained with the small farm group growing EVs in rabi season 1977-78 (Table 5.13). These latter results are as expected, since, as has been discussed earlier, EV growers were not able to control the incidence of attack by the brown plant hopper with pesticides as could the LSV growers.[18] This suggests that the use of LSVs gave the small farm group a decision making advantage over those using EVs, in that it was able to optimise the use of the pesticide variable. Thus, only the small farm group growing LSVs in kharif season maximised its profits by applying optimum levels of all inputs.

Absolute Efficiency of the Large Farm Group: The null hypothesis of absolute price efficiency of the large farm group engaged in the cultivation of LSVs in kharif season was tested (Table 5.11) and showed that the

---

16 Aitken's generalised least squares estimation, with the restrictions on the parameter imposed by Lagrangian multipliers, as used by Byron, enabled us to test which of the k_i was different from unity. This was discussed in Chapter 3.

17 A direct test of equality between MVP and MC was not attempted because it needs the assumptions of considering all the other inputs at the geometric mean level. However, the equality between MVP and MC can be inferred from the statistical significance of λ.

18 However, small farm groups growing EVs in both seasons used other variable inputs of labour, fertiliser and animal power in an optimising way.

hypothesis cannot be rejected at the 10 per cent level. Thus, the large farm group growing LSVs in kharif season maximised its profits by employing the optimum level of all inputs and its price efficiency parameters were $k_s^L = 1$ for s = 1,2,3,4. The null hypothesis of absolute price efficiency of the large farm group growing EVs in kharif and rabi seasons was rejected, as the χ^2 values were significant at the 5 per cent level in both cases (Tables 5.12 and 5.13). Thus, as for small farm groups above, the large farm group growing EVs was not able to maximise its profits by optimising the levels of inputs applied. Once again, our tests showed they were able to equate marginal value product with marginal cost for all variable factors of production except pesticides, as the concerned λ was statistically significant at the 5 per cent level in either season (Tables 5.12 and 5.13).

Thus, given the equal opportunities for both small and large farm groups provided by the HYVP in relation to availability of and access to inputs, the analysis shows that both groups maximised their profits only when they grew LSVs, while in neither season could EV growers do so, because they were unable to optimise their use of pesticides.

Constant Returns to Scale: A test for constant returns to scale in use of factors of production was used to examine further the findings of equal relative efficiency of production based on the validity of profit maximisation discussed above among the sample farm groups. This involved the hypothesis,

$$H_0 \quad : \quad \alpha_1^* + \alpha_2^* = 1 \tag{5.9}$$

which means that constant returns to scale in all factors of production prevail, provided the parameters relating to fixed factors of production in the profit functions add up to unity.[19] This hypothesis could not be rejected for LSVs and EVs in kharif season or EVs in rabi season at the 10 per cent level (Tables 5.11 to 5.13),[20] and thus reinforces the findings of equal relative efficiency among large and small farmer groups.

Summary and Conclusions

The foregoing analysis indicates that irrespective of variety and season, there were no differences between the small and large farmer groups in the study area in relation to the availability and use of inputs. It also showed that both farm groups were relatively equally efficient economically,[21] as well as being price and technically efficient[22] in producing HYVs of paddy in both seasons. This result strongly supports the view that all sample farmers had the same economic motivation of maximising profits by optimising resource use. This conclusion has implications for policies, with respect to farm size, for, given the same access to inputs and on equal terms, small farmers will respond to economic opportunities in the same way as large farmers. However, in order to achieve this, special

---

19 The derivation of this result, is given in Lau, L.J. and P.A. Yotopoulos (1972) (pp.13-14).

20 For the EV growers in both kharif and rabi seasons, the price efficiency parameter of $k_s^i = 1$ $i = L, S$ for $s = 1,2,4$ and not 3, was assumed, i.e., the farmer groups growing EVs in both seasons used optimising levels of labour, fertiliser and animal power but not pesticides.

21 Our intention here was to see whether, given equal opportunities the small farm group and the large farm group produced each of these two varieties efficiently. No direct statistical comparison was made to test whether LSV and EV growers were equally efficient economically.

22 When measured from a maximum feasible yield function (frontier production function) most of the individual farmers showed technical inefficiencies in the production of HYVs which was shown in Chapter 4 above. But on the average, the small farm group and the large farm group were equally efficient technically, as measured through profit and factor demand functions.

institutional arrangements may be necessary to ensure equal access for small farmers to inputs and on equal terms. These points were given further weight by the existence of constant returns to scale in the factors of production.

The results of tests of absolute price efficiency of small and large farm groups inform us about the profit maximising behaviour of these groups. It is interesting to note that LSV growers in kharif were equating the marginal value product with the marginal cost of the variable factors of production, and were thus successfully maximising profits. The EV growers, on the other hand, did not maximise their profits in either season since their price efficiency parameter k_i in the demand function for the single factor of pesticide differed from unity. This divergence can be explained by the biological characteristics of EV, which were discussed earlier in relation to production function analysis. Though the farmers were applying the recommended doses of pesticides, they were unable to control completely the build-up of pests (BPH), given the relatively longer duration of the EV, so, the MVP of pesticides fell below its marginal cost. Because of the relatively shorter duration of LSVs, the pesticides had a more considerable effect in controlling BPH on these varieties. The analysis suggests that this biological characteristic of LSV enabled its growers to maximise profits more closely and thus gave LSV growers an advantage over EV growers in decision-making. With this exception, economic opportunities provided by the HYVP were utilised efficiently by sample participants regardless of farm size.

CHAPTER 6

BENEFITS FROM THE HYVP AND THEIR DISTRIBUTION

Earlier chapters showed that there were no significant differences among large and small farms on a per acre basis in the use of inputs and their economic efficiencies. These analyses were based on the observations collected from the 91 sample participants representing both owner and tenant cultivators in kharif and rabi seasons. In this chapter, the distribution of residual income among the owner cultivators (79 in kharif and 81 in rabi) are discussed. In the light of earlier results, it is expected that the distribution of residual income should be determined by the pattern of land ownership distribution in either season. It was argued earlier that the distribution of gains from LSVs depends on a number of factors in the HYVP besides the location specific seeds. The impact of these factors on the pattern of distribution of benefits needs to be analysed separately, to judge correctly the effects of using LSVs on the distribution of gains from the HYVP. Subsequently it was shown that sample participants do avail themselves of the opportunities offered by the HYVP and that this participation was efficient economically. Also, it was found that the LSV growers were maximising profits by equating marginal value product with marginal cost of variable factors of production, while EV growers could not do so, mainly because these varieties were more susceptible to pests, and especially to the brown plant hopper. This suggests that there may be differences in the distribution of benefits between LSV and EV growers. Since, as shown earlier opportunities were equally available to cultivators of LSVs and EVs in the study area, any difference between their distributions of gains will be mainly because of varieties.

The questions examined here are, the levels of net benefits gained at farm level from the new technology based on LSVs and their distribution between farmers in the survey area. The following analysis of the monetary performance of LSVs includes a comparison with that of EVs by measuring changes in incomes of farmers according to operational holding groups.[1]

There is a strongly held view that the benefits of the new technology have not been shared equally between regions or amongst groups of holdings in the same area.[2] On these grounds, it is argued that the HYVP has not been successful, and involves conflict between the achievement of the objectives of growth and social justice. In this study therefore, an attempt has been made to examine the impact of the HYVP on the distribution of net gains among different holdings in the study area.

Sections below discuss distributional aspects of the HYVP as a whole (with LSVs and EVs taken together) in the study area, compare gains for LSV and EV growers and their distribution, and finally reach conclusions concerning distributional aspects of the modified HYVP.

Distribution of Income from the HYVP

The distributional pattern of income (total revenue less total variable costs) shows that more than one third of sample participants received income of less than Rs. 1000 per acre and that this applied to small and large farmers more or less alike (Table 6.1). Only 13 per cent of all sample farmers growing HYVs in kharif season earned income above Rs. 2000 per acre, and again the shares of small and large farmers were fairly similar.

---

1 Data availability restricted our analysis to the impact of the HYVP on income alone. Analysis of employment generation, particularly for landless labourers could not be attempted in this study. It may be noted again that income in this chapter refers to farm residual income.

2 A brief, but comprehensive discussion is given in Byres, T. (1972).

TABLE 6.1

DISTRIBUTION OF INCOME PER ACRE FROM THE HYVP IN KHARIF SEASON BY SIZE OF HOLDINGS

Income/Acre (Rs.)	Percentage of Sample Participants		
	Total	Small	Large
Below 1,000	38.46	41.30	35.56
1,000-1,500	29.68	26.09	33.33
1,500-2,000	18.68	17.39	20.00
Above 2,000	13.18	15.22	11.11

The distribution pattern for rabi season (Table 6.2) is similar, though there was a lower 6 per cent of sample farmers in this season who earned income above Rs. 2000 per acre.

TABLE 6.2

DISTRIBUTION OF INCOME PER ACRE FROM THE HYVP IN RABI SEASON BY SIZE OF HOLDINGS

Income/Acre (Rs.)	Percentage of Sample Participants		
	Total	Small	Large
Below 1,000	58.57	60.00	57.14
1,000-1,500	25.71	25.71	25.71
1,500-2,000	10.00	8.57	11.43
Above 2,000	5.72	5.72	5.72

Thus there was a heavy concentration of farmers who receive less than Rs. 1500 per acre in both seasons. Literature on the 'green revolution' suggests that such variation in earnings per acre might well be connected with size of holding. Table 6.3 shows that there is considerable inequality in the distribution of operational holdings among the participants in kharif season. The bottom 45 per cent of smallest farmers operated an average farm size of 1.22 acres and their total operational holdings comprised only 17.56 per cent of total area of operational holdings, while the top 10 per cent of largest farmers operated an average of 10.81 acres and their total was almost 35 per cent of total area sampled. In

TABLE 6.3

DISTRIBUTION OF OPERATIONAL HOLDINGS, TOTAL AREA AND INCOME BY FARM SIZE GROUP AMONG THE SAMPLE PARTICIPANTS, KHARIF SEASON, 1977

Size Group (acres)	Percentage of Farms	Average Size of Farm (acre)	Percentage of Area to Total	Percentage Distribution of Income
Below 1	12.09	0.68	2.55	2.43
1 -1.50	17.58	1.09	5.98	5.63
1.51-2.00	15.38	1.88	9.03	9.55
2.01-2.50	9.89	2.38	7.35	6.97
2.51-3.00	14.29	2.93	13.12	12.32
3.01-4.00	9.89	3.53	10.92	11.74
4.01-6.00	9.89	5.29	16.36	20.13
6.01-10.00	6.59	7.24	14.92	15.73
Above 10	4.40	14.38	19.77	15.50
Total	100.00		100.00	100.00

rabi season (Table 6.4) the bottom 50 per cent of participants on the average had an operational holding of 1.21 acres and their share of total operational holdings surveyed was 21 per cent, while the top 10 per cent of farmers had an average sized holding of 8.93 acres and their total operational holdings comprised about 27 per cent of the area surveyed.

TABLE 6.4

DISTRIBUTION OF OPERATIONAL HOLDINGS, AREA OPERATED AND INCOME AMONG SAMPLE PARTICIPANTS GROWING HYVs IN RABI SEASON, 1977-8

Size Group (acres)	Percentage of Farms	Average Size of Farm (acre)	Percentage of Area to Total	Percentage Distribution of Income
Below 1	11.43	0.66	2.56	2.03
1 -1.50	18.57	1.08	6.87	6.00
1.51-2.00	18.57	1.88	11.90	12.95
2.01-2.50	10.00	2.41	8.21	5.87
2.51-3.00	10.00	3.00	10.24	7.74
3.01-4.00	10.00	3.54	12.06	14.44
4.01-6.00	11.43	5.32	20.76	20.47
6.01-10.00	7.14	6.83	16.65	19.84
Above 10	2.86	11.03	10.75	10.65
Total	100.00		100.00	100.00

To examine further the concentration of income among the participants, the decile distribution of income in the study area was calculated for kharif (Table 6.5) and rabi (Table 6.6) seasons. This was worked out by dividing holdings into decile holding size groups and

TABLE 6.5

PATTERN OF DISTRIBUTION OF INCOME OF HYV GROWERS IN KHARIF 1977 BY DECILE GROUPS OF HOLDINGS

Decile Group	Percentage of Income	Cumulative Per Cent of Income
I	2.26	2.26
II	3.06	5.33
III	5.04	10.36
IV	6.42	16.78
V	7.12	23.90
VI	7.10	31.00
VII	10.33	41.33
VIII	12.37	53.70
IX	20.66	74.36
X	25.64	100.00

TABLE 6.6

DISTRIBUTION OF INCOME AMONG SAMPLE PARTICIPANTS GROWING HYVs IN RABI SEASON BY DECILE GROUPS

Decile Group	Percentage of Income	Cumulative Per Cent of Income
I	2.02	2.02
II	2.68	4.70
III	3.45	8.15
IV	4.57	12.72
V	5.88	18.60
VI	9.57	28.17
VII	12.30	40.47
VIII	13.10	53.57
IX	15.73	69.30
X	30.70	100.00

calculating the share of total income for each of the decile groups. Table 6.5 shows that there is considerable inequality in the distribution of income among the participants in kharif season. The 30 per cent (Deciles I to III) smallest farms received only 10 per cent of income from the HYVs, 50 per cent smallest gained only 25 per cent, while the 20 per cent (Deciles IX and X) largest farmers received 46 per cent of total income. In rabi season (Table 6.6), the 30 per cent smallest farms received a lower 8 per cent of total income and the largest 20 per cent of farms gained 46 per cent, as in kharif season.

Figure 6.1 compares the Lorenz curve for the distribution of income drawn from Table 6.5 with that drawn from Table 6.6. Throughout the range of observations the curve showing the distribution of income for rabi lies below that for kharif season, and the Gini index of inequality[3] for the rabi curve is 0.4266, which is greater than that for kharif season (0.3903). Thus the distribution of income in rabi season is more unequally distributed than in kharif season. More notably, however, there is considerable inequality in income distribution in both seasons.

---

3 With the assumption that the character is uniformly distributed within each class, the curve of concentration becomes identical with the broken line which joins the known points of the curve and the index of concentration is obtained from the following formula,

$$R = 1 - \sum_{i=0}^{n-1} (p_{i+1}-p_i)(q_{i+1}+q_i)$$

where p_i represents the ratio of the number i of the lowest income (profit) receivers to the total number n of all income receivers and q_i refers the ratio of the amount of the i lowest incomes to the total amount of all n incomes. [Gini, C. (1962) 'Statistical methods with special reference to agriculture', Metron, Vol.XXII, Nos.1-2, pp.169-75 .] It is possible to estimate the Gini coefficient by more sophisticated method, such as fitting a Beta function to the Lorenz curve, but such methods were not used here because the straight line approximation to the index of inequality works out to be quite satisfactory if the number of population groups is not less than 8. [Gartwirth, J.L. (1972) 'The estimation of the Lorenz curve and Gini index', Review of Economics and Statistics, Vol.54, No.3, pp.306-16.]

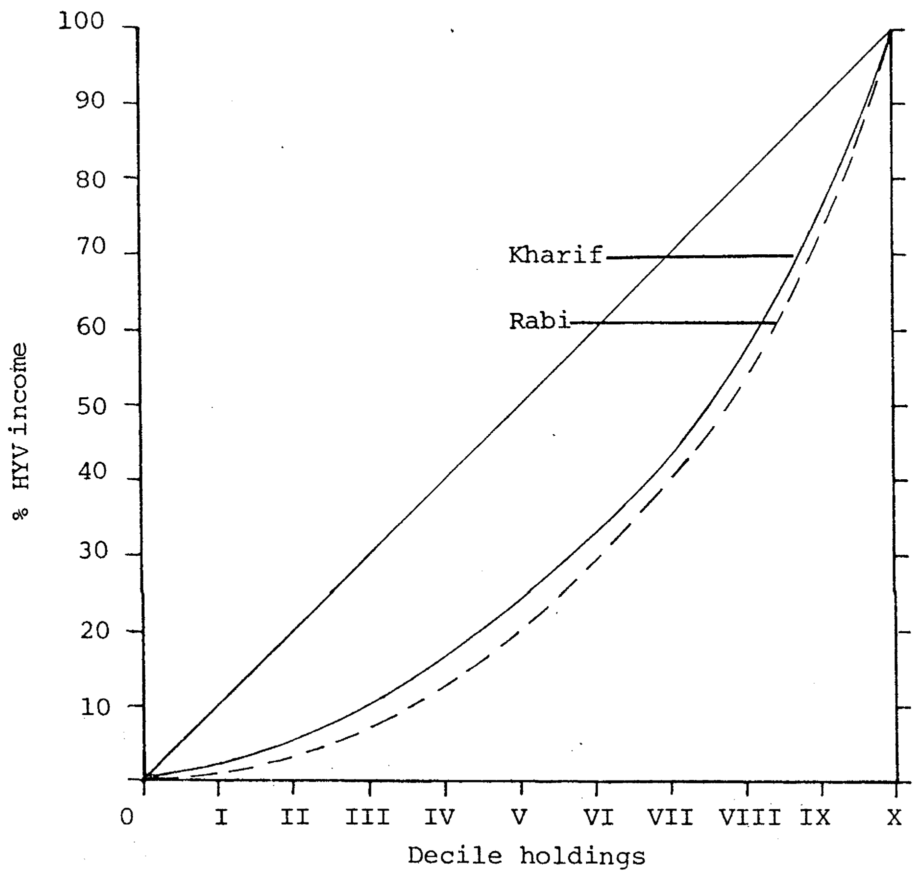


FIGURE 6.1: Lorenz curves showing income distributions for HYVs by season

If as the foregoing analysis showed, the opportunities provided by the HYVP were equally available to all farms, and farmers wanted to maximise profits, the question remains as to why this degree of inequality in income distributions exists in both seasons. In analysing reasons for the inequality of gains revealed in this study, three important factors are considered:

a. unequal distribution of ownership of operational holdings;

b. unequal distribution of input applications per acre between farm size groups; and

c. different yield responses from same level of input applications per acre between operational holdings.

The impact of these three factors on the distribution of profits in the study area is examined below.

The pattern of distribution of land ownership in kharif season (Table 6.7) shows a relatively heavy concentration of ownership in the top 20 per cent of HYV growers with largest farm sizes. The 20 per cent with largest farms (Deciles IX and X) owned 50% of total area of operational holdings, while the 30% of smallest farms owned only 9% of that area. This is illustrated with a Lorenz curve in Figure 6.2. Comparison of this with the distribution of income by decile group (Table 6.5) shows great similarities. In the latter, the 30% of smallest farm earned 10% of income, and the 20% largest farms earned 46%. In Figure 6.2, the two Lorenz curves almost coincide which suggests that the distribution of land ownership is a key, if not the key factor in the distribution of income The slope of the curve showing the distribution of ownership of holdings is

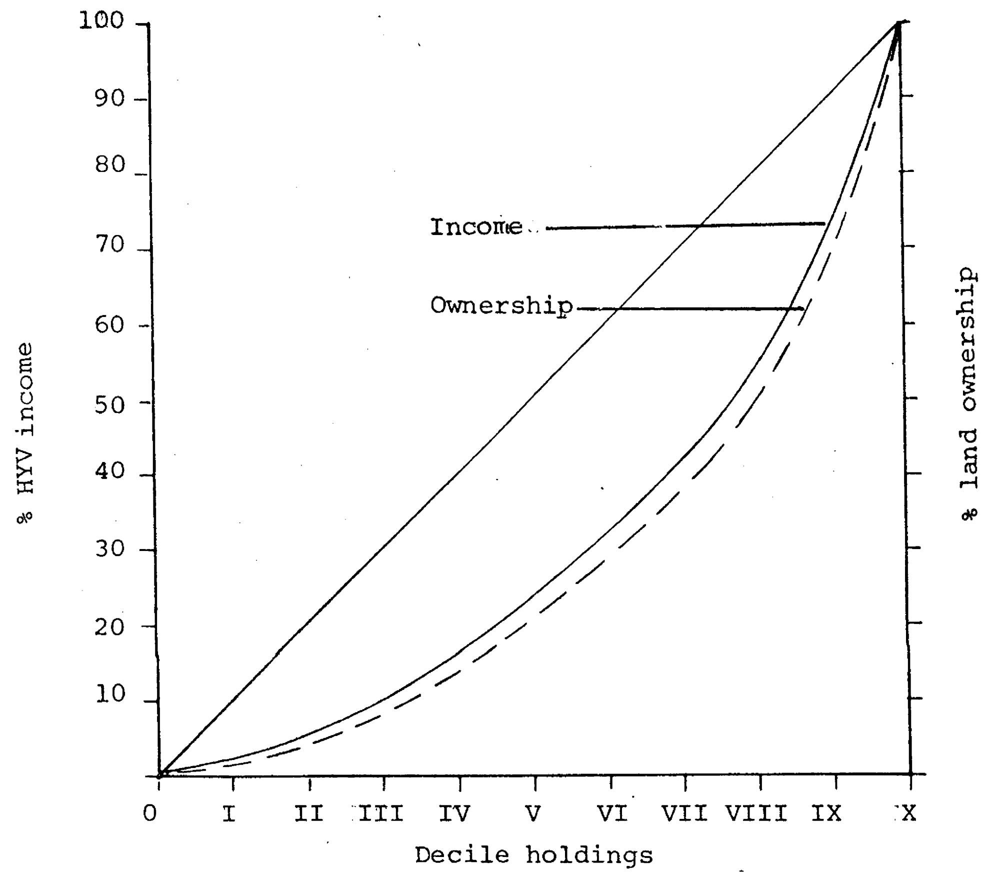


FIGURE 6.2: Lorenz curves showing distributions of income and land ownership for HYVs in kharif season, 1977

TABLE 6.7

DISTRIBUTION OF LAND OWNERSHIP BY DECILE GROUPS OF SAMPLE HYV GROWERS, KHARIF SEASON, 1977

Decile Group	Percentage of Area Owned	Cumulative Per Cent of Area Owned
I	2.22	2.22
II	3.08	5.30
III	4.07	9.37
IV	5.74	15.12
V	6.55	21.67
VI	8.11	29.78
VII	9.49	39.22
VIII	11.23	50.45
IX	17.09	67.54
X	32.46	100.00

greater than that of the curve depicting the income distribution throughout the range of observation. The latter curve lies above the former and the Gini index of inequality for the curve showing ownership of holdings is 0.4207 as against 0.3903 for income distribution. However, before concluding that both small and large farms benefited according to their share of area of total operational holdings, it is necessary to determine whether the difference in inequality between these two distributions is statistically significant. No statistical tests are available for comparing the Gini concentration indexes. However, the variances of the logarithms of the variables can be considered as a measure of inequality,[4]

4 Theil, H. (1967) Economics and information theory, North-Holland Publishing Company, Amsterdam, (pp.121-25).

and statistical tests are available to observe the significance of differences between two variances[5] of the logarithms of variables. With the assumption that the operational holdings and income are log-normally distributed, with mean μ and variances σ_1^2 and σ_2^2, the differences between σ_1^2 and σ_2^2 were tested for significance.[6] The calculated F-ratio $(\frac{\sigma_1^2}{\sigma_2^2})$ for the variances of logarithms of income to that of ownership holdings is 1.26. As their calculated value is not greater than the tabulated F-value 1.35 for (91,91) degrees of freedom at the 10 per cent level, the null hypothesis of no difference between the inequality indexes cannot be rejected statistically.

As might be expected, the pattern of ownership of holdings in rabi season follows a similar distribution to that in kharif season (Table 6.8 and Figure 6.3). The calculated Gini index of inequality for the distribution of ownership of holdings (0.4515) is also very similar to that for kharif season. The null hypothesis of no differences between the inequality indexes of holding ownership and income cannot also be rejected at the 10 per cent level (the calculated F-ratio is 1.17 which is less than the tabulated F-value 1.38 for (70,70) degrees of freedom at the 10 per cent level).

---

5 The variances for example, of the logarithms of income can be computed with the following formula:

$$\frac{1}{N} \sum_{i=1}^{N} (\ln Z_i - \ln Z)^2 = \frac{1}{N} \sum_{i=1}^{N} (\ln \frac{Z_i}{Z})^2$$

where Z_i is the income of the i^{th} farm; Z refers to the geometric mean profit of all farms and N is total number of farms.

6 The ratio of variances follows an F-distribution and the differences between variances are significant if the calculated F-ratio is significant statistically.

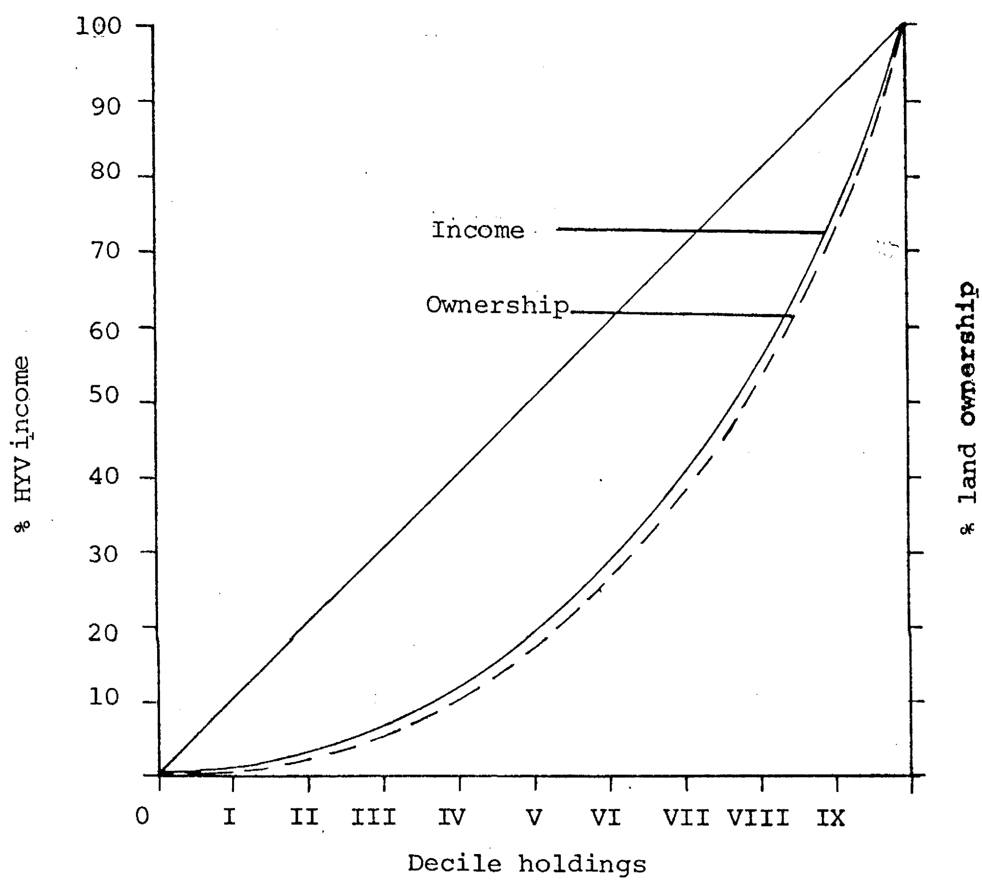


FIGURE 6.3: Lorenz curves showing distributions of income and land ownership for HYVs in rabi season, 1977-8

TABLE 6.8

DISTRIBUTION OF LAND OWNERSHIP BY DECILE GROUP OF SAMPLE HYV GROWERS, RABI SEASON, 1977-78

Decile Group	Percentage of Area Owned	Cumulative Per Cent of Area Owned
I	1.98	1.98
II	2.66	4.64
III	3.21	7.85
IV	4.06	11.91
V	5.32	17.23
VI	9.08	26.31
VII	11.89	38.20
VIII	12.86	51.06
IX	15.02	66.08
X	33.92	100.00

These results suggest that the distribution pattern of income is largely explained by the pattern of distribution of holding ownership in both seasons. Beyond this, another possible determining factor will be the level of inputs applied by sample participants.

The pattern of distribution of inputs applied is described adequately by the distribution pattern of total expenditure on inputs.[7] The distribution pattern of total expenditure on inputs among the decile groups of holding growing HYVs in kharif and rabi seasons (Tables 6.9 and 6.10) closely follows that of the ownership pattern in both seasons. Lorenz

---

7 Shand used the level of nitrogenous fertiliser applied per holding for lack of data on total input expenditure. [Shand, R.T. (1978)(pp.12-26).

TABLE 6.9

DISTRIBUTION OF TOTAL EXPENDITURE ON INPUTS OF HYV SAMPLE GROWERS IN KHARIF 1977 BY DECILE GROUPS

Decile Group	Percentage of Total Expenditure	Cumulative Per Cent of Total Expenditure
I	2.23	2.23
II	3.08	5.31
III	4.75	10.06
IV	5.27	15.33
V	7.20	22.53
VI	7.54	30.07
VII	9.57	39.64
VIII	11.48	51.12
IX	17.20	68.32
X	31.68	100.00

TABLE 6.10

DISTRIBUTION OF TOTAL EXPENDITURE ON INPUTS OF HYV SAMPLE GROWERS IN RABI 1977-78 BY DECILE GROUPS

Decile Group	Percentage of Total Expenditure	Cumulative Per Cent of Total Expenditure
I	2.00	2.00
II	2.67	4.67
III	3.30	7.97
IV	4.39	12.36
V	5.60	17.96
VI	9.47	27.43
VII	12.01	39.44
VIII	12.80	52.20
IX	15.26	67.46
X	32.54	100.00

curves (Figures 6.4 for kharif and 6.5 for rabi) for ownership and expenditure patterns underline the similarity, with the curve of the latter lying slightly above that of ownership distribution, but below the curve for the distribution of income in both seasons. Thus the ownership distribution seems to be the most unequal of the three distributions in both seasons. The concentration index for the distribution of total expenditure was 0.4130 for kharif and 0.4390 for rabi season as against 0.4207 and 0.4515 for ownership distribution in these seasons.

To test the hypothesis that the pattern of input expenditures reflects the distribution pattern of ownership of holdings, the ratio of the variances of logarithms for expenditure to that of ownership was calculated for both seasons. The ratios[8] were not significant at the 10 per cent level in both cases, which means that there was no significant difference between the two distributions. This bears out the qualitative evidence and argument presented in Chapter 5 that farmers had more or less similar access to inputs regardless of size of holdings, and there was no significant differences between the average input applications of large and small farmers.

To sum up, the analysis shows that the crucial factor determining the distribution of income was the pattern of land ownership. The fact that there were no significant differences in the pattern of input expenditure from that of land ownership follows from the fact that there was no serious constraints on input availability and use which could distort the distribution pattern of income.

---

8 The calculated F-ratios for kharif and rabi seasons are 1.12 and 1.02 respectively which are not greater than the tabulated F-values 1.35 for (91,91) degrees of freedom and 1.38 for (70,70) degrees of freedom at the 10 per cent level respectively.

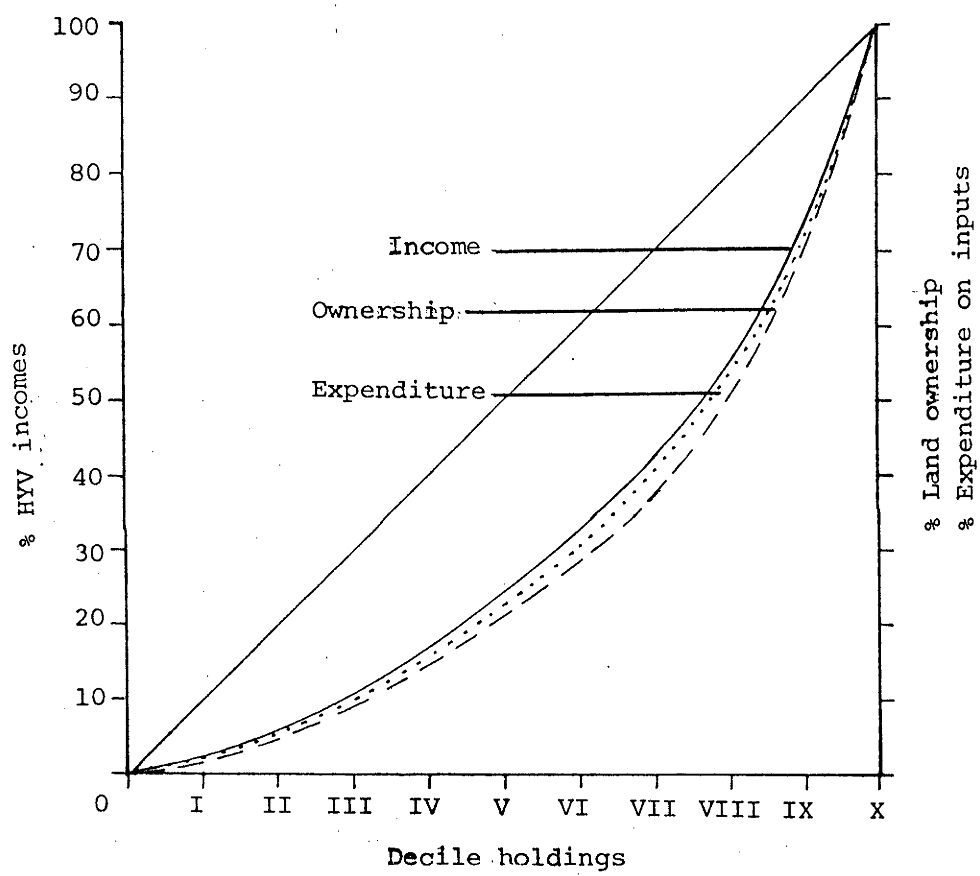


FIGURE 6.4: Lorenz cures showing the distributions of incomes, land ownership and expenditure on inputs for HYVs in kharif season, 1977

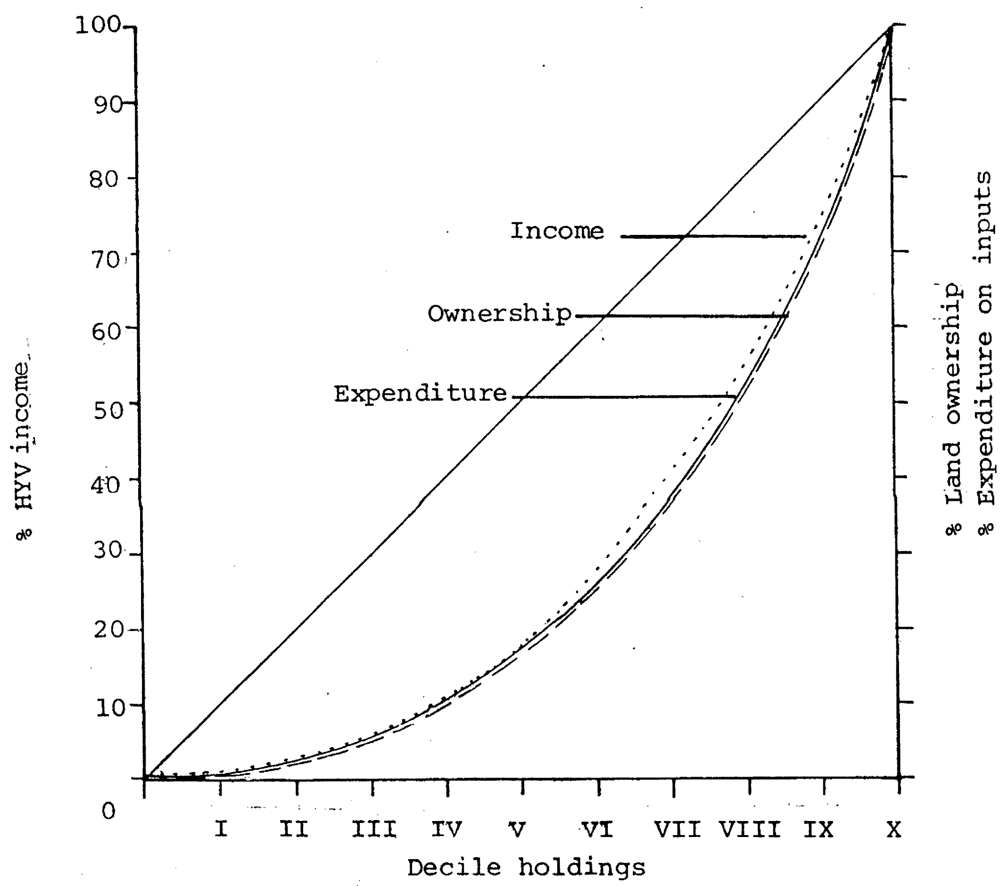


FIGURE 6.5: Lorenz curves showing the distributions of income , land ownership and expenditure on inputs for HYVs in rabi season, 1977-8.

Comparison of the Distribution of Income from LSVs and EVs

As the yield per acre for LSVs was higher than that for EVs at roughly the same input levels, we might expect higher profits for LSV growers. However, profits are also determined by prices and the survey showed that EVs commanded a higher price than LSVs in the study area because of their long standing popularity amongst consumers.[9] The novelty of the new LSVs to consumers was the main reason for their lower price. But even with lower price, the higher yields of LSVs gave total revenue substantially greater than that from EVs. Average yields per acre for sample participants using LSVs and EVs, estimated from production function (4.4) and assuming mean levels of inputs were 2.45 and 1.64 tons per acre respectively. Using average prices for LSVs and EVs, total revenue was 25.3 per cent higher for LSVs.

Income for LSV growers were also generally higher (Table 6.11). The group with income per acre below Rs. 1000 had a smaller percentage of participants using LSVs (13.2%) than in the case of EVs (25.3%). The proportion of LSV growers in the group earning highest profits (above Rs. 2000 per acre) was 8.79 per cent, while that of EV growers was 4.39 per cent. Survey evidence thus shows that the LSVs have improved net incomes of farmers over earnings from EVs in kharif season.

Since the difference between LSVs and EVs was almost purely a matter of yield, and participants utilised the inputs in similar fashion, any significant differences between the distributions would suggest additional factors were at work through the LSVs. The patterns of both

9 The average price for EVs per 100 Kgs. was Rs. 155 and that of LSVs was Rs. 130 in 1977.

TABLE 6.11

PERCENTAGE DISTRIBUTION OF INCOME PER ACRE AMONG THE PARTICIPANTS GROWING LSV AND EV IN KHARIF BY DIFFERENT PROFIT GROUPS

Size Group (Rs.)	LSV Growers (%)	EV Growers (%)	Total Growers (%)
Below 1,000	13.19	25.27	38.46
1,000-1,500	18.68	11.00	29.68
1,500-2,000	10.99	7.69	18.68
Above 2,000	8.79	4.39	13.18

distributions of income were compared using decile groups of farm holdings size (Table 6.12). These show considerable inequalities for both varieties. The 30 per cent of farmers with smallest income received

TABLE 6.12

DISTRIBUTION OF INCOME AMONG SAMPLE PARTICIPANTS GROWING LSV AND EV IN KHARIF BY DECILE GROUPS,1977

Decile Groups	LSV		EV	
	Per Cent of Income	Cum.Percentage Income	Per Cent of Income	Cum.Percentage Income
I	2.74	2.74	2.62	2.62
II	2.76	5.50	3.62	5.24
III	5.10	10.60	4.17	9.41
IV	6.10	16.70	4.66	14.07
V	6.83	23.53	8.04	22.11
VI	8.68	32.21	7.53	29.64
VII	11.33	43.54	9.96	39.60
VIII	14.73	58.27	12.61	52.21
IX	15.12	73.39	16.27	68.48
X	26.61	100.00	31.52	100.00

only 11 per cent (LSVs) and 9 per cent (EVs) of income while the top 20 per cent received 42 per cent (LSVs) and 48 per cent (EVs). These distributions were further illustrated using Lorenz curves (Figure 6.6) using the cumulative proportions of farms and income. The plotted curves show that there was less inequality in the distribution of income from LSVs than there was in the distribution from EVs, i.e., the former curve lies above the latter and closer to the line of equality.

The Gini indexes of inequality for the distribution of income were calculated as 0.3698 for LSVs and 0.4157 for EVs. The difference between these two indexes was tested. The standard deviations of the logarithms of LSV income and EV income worked out to be 0.948 and 1.171 respectively. The null hypothesis of no difference between the variances of the logarithms of LSV profits and EV profits was rejected statistically at the 10 per cent level (the calculated F-value 1.53 was greater than the tabulated F-value 1.50 for (41,50) degrees of freedom). Thus, the magnitude of the inequality in the distribution of profits from LSVs was significantly less than that arising from EVs in kharif season.

There are a large number of possible reasons for this difference in inequality in the two curves for profit distributions. Differences in the distribution of land ownership between the two groups could be one possible explanation. The standard deviation of logarithms of ownership of holdings of LSV growers was 0.79 and that of EV growers was 0.82. Statistical testing of the ratio of variances of the EV land ownership to LSV land ownership showed that the null hypothesis of no difference between the two distributions could not be rejected at the 10 per cent level (the calculated F-value 1.08 was less than the tabulated F-value 1.50 for (41,50) degrees of freedom).

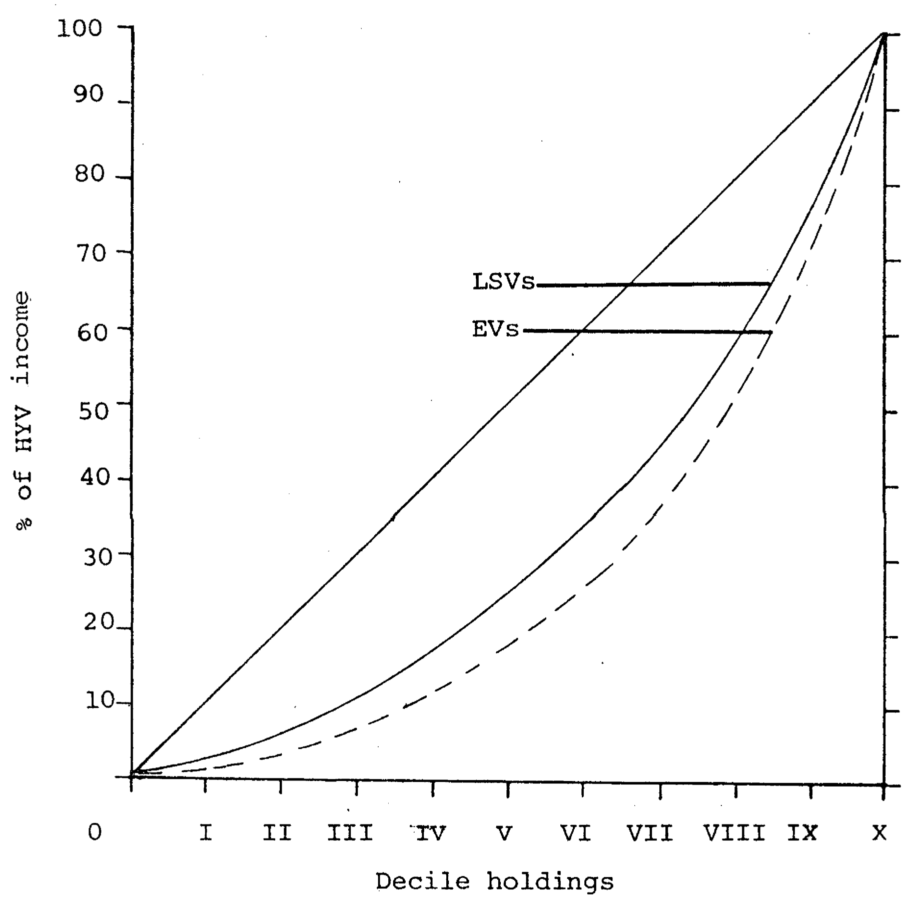


FIGURE 6.6: Lorenz curves showing the distributions of income for LSVs and EVs in kharif season, 1977

Earlier chapters showed that both LSV and EV growers were cultivating under homogeneous production conditions including the same socio-economic environments. The only difference between the two groups was the seed itself. It was shown that the difference between the varieties was evident in the relative yields between LSVs and EVs. Thus, the factor most responsible for the difference in inequality indexes may be that the superiority of yields of small farmers over large farmers growing LSVs was greater than those growing EVs. Thus, the extent of the inequalities in the profit distribution was narrowed with LSVs. This, however, could not be proved statistically and in any case was not a major change.

Summary and Conclusions

As in other parts of India, and in other countries as well, there is inequality of incomes among farmers mainly because of differences in their ownership of land. In our sample, the distribution of owned land is practically the same as the distribution of operational holdings because there are very few cases of tenant farmers. Therefore, we have used the operational holding for our analysis. The main point that we have investigated in this Chapter is whether on top of the inequality in the distribution of land whether there is any additional inequality due to the differential access and use of inputs associated with the HYVP between large and small farmers. Such additional inequality has been reported from some other countries. However, for the sample area the above analysis does not show any significant amount of inequality from this source.

CHAPTER 7

SUMMARY AND CONCLUSIONS

In the early years of the new rice technology, imported or exotic high yielding varieties were distributed with little or no adaptive research and in general performed poorly at farm level. Attempts were then made in a few centralised research stations to produce HYVs that incorporated more desirable characteristics of local varieties but which would be widely suited to Indian conditions. Again, these made no substantial contribution to total crop output, largely because of the great diversity in paddy growing conditions which restricted their field performance and thus their adoption by farmers. It was then realised that paddy breeding research should be decentralised to take particular account of local and seasonal combinations of agro-ecological conditions for rice growing. This gave rise to a new modified approach to the HYVP for paddy, in which emphasis was given to cross breeding of EVs with local or local improved varieties to incorporate characteristics of the latter that enabled adaptation to production conditions and marketing requirements at the local level, whilst retaining the high yielding characteristic of the EVs. This emphasis on evolving location-specific high yielding varieties is clearly to be a crucial factor in the quest for increasing productivity in paddy growing areas of India.[1] It is therefore appropriate and timely to analyse the

1 Crawford recently made a strong case for such emphasis in agricultural research priorities in India, see Crawford, J.G. (1979) 'Research in agricultural policy', a lecture delivered to the Golden Jubilee of the Indian Council of Agricultural Research, New Delhi on 3rd September, 1979.

early 'field performance' of such LSVs and thus offer an evaluation of the contribution of this approach to paddy production.

This thesis is a study of this new approach in a leading area, i.e., in Coimbatore district in Tamil Nadu in south India. Coimbatore was previously identified as one in which the HYVP had progressed well in terms of availability of LSVs adapted to local growing conditions, HYV area coverage, levels of packages inputs applied, and yields. The study has attempted to measure the benefits accruing to farmers from the evolution and introduction of LSVs in the context of this 'successful performance' in Coimbatore district.

During the field survey year of 1977-8, district level data showed that in kharif season, HYVs were grown almost exclusively, and that in recent years the proportion of area under LSVs to total HYV area has been substantial and growing. In 1978 rabi season, more than 80 per cent of areas were under HYVs with a limited area under local or local improved varieties but more under LSVs. In kharif season, an exotic HYV, IR20, had been the popular variety till recently when it was successfully challenged and progressively replaced by recently evolved LSVs, such as ADT-31 and CO-27. In rabi season IR20 has continued to dominate paddy and HYV area. A majority of farmers in Coimbatore district applied more than the recommended levels of chemical fertilisers, and of preventive and curative measures of plant protection chemicals. Average yields obtained from HYVs were high.

Coimbatore district had a particularly favourable environment for the HYVP. It had a good surface water supply and overall, almost 60 per cent of sown area in the district was irrigated either by canal, tanks or wells

This district was well served by the paddy breeding station of the Tamil Nadu Agricultural University where a programme to produce LSVs to suit the range of local growing conditions within Tamil Nadu had been in progress for some years. State farms and registered growers multiplied HYV seeds. During the time of the survey, there was no shortage of seeds, nor was there any difficulties in seed distribution. With a considerable number of private and co-operative distribution points, the supply of chemical fertilisers and plant protection chemicals in the district was adequate and timely. Farmers also enjoyed an adequate and timely supply of credit provided by financial institutions such as co-operative societies and commercial banks. The primary co-operative societies functioned efficiently with very low numbers of defaulters annually. The Agricultural Department actively engaged in supplying inputs and providing extension guidance to farmers, and they in turn were enthusiastic about growing HYVs and increasing their yields per acre. Thus Coimbatore district was favourably placed for the HYVP in terms of quantity and quality of resources and inputs, institutional and administrative arrangements, and thus represented an appropriate survey area for the present study.

The performance of the modified HYVP utilising LSVs, in Coimbatore district was analysed through a purposively selected sample of farmers from a single selected village, in two paddy growing seasons of the crop year 1977-8, by examining:

a. Physical performance which showed the productive capacity and realised yields of LSVs;

b. economic performance which showed the economic opportunities provided by the HYVP and participants' responses to it; and

c. distributional performance which showed the pattern of distribution of benefits among participants using LSVs.

These measures of performance of success using LSVs were all compared with those of the existing EVs in the study area so as to judge the relative contribution of LSVs and EVs in this chosen environment.

Physical Performance: Using the neo-classical production function, it was found that there had been a substantial upward shift in the location of the production curve with the introduction of LSVs in kharif season in the study area, with a 50 per cent yield improvement over the level attained by EVs. This was achieved mainly because of two characteristics of LSVs: an inherently higher yielding capacity and a shorter maturity period which effectively reduced their susceptibility to brown plant hopper. The introduction of LSVs helped at least partially to lift this major biological constraint on EV yields. The current LSVs, however, were by no means the final answer to the control of BPH in kharif season. Ideally LSVs are needed that are totally resistant to BPH.

The breeding programme had not evolved LSVs that were superior to EVs currently in use in rabi season in the study area, and indicates an area in which the varietal breeding programme could make a substantial further contribution to increasing productivity of paddy production. If short duration LSVs were available for both seasons, Gobichettipalayam block might possibly be converted from a two to a three crop area, using existing irrigational facilities. The varietal breeding programme might thus be able both to increase the productivity of land and to transform the cropping system.[2]

2 Barker, R. et al. (1975).

The study also showed that yields could further be increased with the existing technology, if participants were to follow the HYVP more closely. This was demonstrated in the study area by applying the concept of maximum feasible yield (MFY) which was estimated by using a maximum likelihood estimation for both seasons. MFY was actually obtained by very few sample participants who did follow the programme very closely, while yields of others who did not use best practices fell short of the MFY.

It is important to note that the MFY of LSVs obtained by some sample participants in kharif season was very close to the experimental maximum yields obtained on the research station of the Tamil Nadu Agricultural University and exceeded the best obtained for the same varieties on Aduthurai Research Station in Tanjore district of Tamil Nadu. These results show that considerable achievements have been realised in the production of paddy in Coimbatore district through the HYVP: (i) appropriate identification of the local growing conditions by the paddy breeding research station and effective evolution of LSVs to suit these local conditions; and (ii) farmers' active participation in the HYVP and their concern to increase yields by following best practices of the programme. However, the latters' performances do not mean that the study area has overcome all the institutional hurdles in the cultivation of LSVs in kharif season.

The analysis showed that differences between the MFY and actual yields for some sample farmers were substantial in both seasons, and these were not due to chance factors, but rather because these farmers did not understand the technology fully. Extension officials had not visited the farms to advise them, and so farmers did not use best practices. The narrow gap between maximum experimental yield and MFY, and the large gap between the MFY and actual yields obtained by sample participants in kharif season suggest that attention should be focussed on extension work and that this should be more closely integrated with research. A major extension problem was identified in the study which led to inadequate and incorrect knowledge of the technology among sample participants. That was inadequacy of extension staff for HYVP needs which constrained mainly the extension officials in giving advice to farmers on important cultural practices of the HYVP. Because of this shortcoming, a majority of sample participants did not realise the MFY. Extension policy should be altered to increase the number of extension officials appointed and to reorganise their duties so as to enable them to spend more time on field visits.

Economic performance of the modified HYVP was seen as an interaction between the opportunities offered by the Programme, and the response of farmers to those opportunities. The physical potential of LSVs and EVs was already determined. Beyond this, the opportunities depended upon the availability of inputs and the terms of their availability. The study, in exploring this concern, found that there was in fact virtually equal access to all inputs on reasonable terms for all farmers in the survey area regardless of farm size. In other words, the institutional constraints on farmers' performances were minimal. Analysis of these performances showed first that there was no significant differences in the application of inputs between small and large farm groups. Second, profit and factor demand function analysis showed that both large and small farmer groups were equally efficient economically in the production of LSVs and EVs in kharif season, and of EVs in rabi season. Third, there were differences in the degree of absolute economic efficiency achieved by growers of these two varietal types. LSV growers in kharif season were able to maximise their profits by optimising levels of use of all inputs. EV growers on the other hand, equated marginal value product with marginal cost of all inputs in both seasons except pesticides. The production function analysis of LSVs and EVs mentioned above suggested that this difference in absolute efficiency between LSV and EV growers was due to differences in the biological characteristics of LSVs and EVs. Data showed that the maturity period of longer duration EVs (130-135) days was favourable to the build up of BPH, led to the likelihood of heavy attacks, and rendered pesticides used to control BPH relatively ineffective. The shorter duration LSVs (105-110 days) did not give the same opportunity for BPH build up and enabled better control with pesticides. These results underline the further priority in varietal breeding programmes of developing pest and disease resistance in LSVs, and again point to scope for further improvement in this direction. They also demonstrate the advantages to farmers and to the performance of the HYVP of the proper functioning of institutions providing inputs (including credit) to all farmers regardless of farm size,[3] for the study showed that without institutional constraints farmers in the study area had the same economically rational response to opportunities for the production of both LSVs and EVs in both seasons.

---

3 Shand, R.T. (1978).

Distributional Performance: The third major question considered was that of absolute and relative levels and distributions of profits among sample participants. It was first shown that, given the equal access to inputs amongst farmers, the HYVP (taking LSVs and EVs together) was size neutral and did not widen the relative income gap within farming communities in the study area. Statistical comparison of measures of inequalities showed that the pattern of income (residual) distribution from the HYVP closely followed the distribution pattern of land ownership in both seasons. This means that the HYVP technology neither improved nor worsened the relative distribution of residual income in the study area. This result together with earlier findings implies that the inequality in income is related to area operated.

Comparison of gross incomes received by LSV growers and EV growers in kharif season showed an average gain for LSV growers of about 25 per cent. Average LSV yields were 50 per cent greater than those of EVs in kharif season, but the average price of LSVs was about 19 per cent less than that of EVs. The survey revealed that EVs commanded a higher price because of their familiarity to consumers. Recently introduced LSVs had similar taste and cooking qualities but being new on the market, brought a lower price. In due course this price differential could be expected to disappear. Its continuation would be a further matter for investigation by plant breeders.

Profits from LSVs were slightly but significantly (10 per cent level) more evenly distributed than those from EVs in the study area. The pattern of distribution of land ownership for LSV and EV growers did not vary significantly in kharif season. The small farmer group of LSV growers obtained slightly higher yields than the large farmer group, but the differences were not statistically significant. The study was not able to identify the causes of the reduction of inequality between the distributions of profits amongst LSV and EV growers. Finally, the analysis showed that, because of the distribution pattern of land ownership, the larger farmers gained most of the profits, though all farmers did benefit.

Conclusions:

This study, limited though it was in terms of survey area and sample, has served to provide some indication of current attainable limits to the performance of the modified HYVP, and the range of actual farm performances in an area without major constraints on performance. Maximum yields attained, admittedly by a relatively few farmers adopting best practices, were close to maximum yields on experiment stations in the same location, and show that there need not be a major gap between these two. The MFY should be seen as a shifting frontier, the location of which is governed primarily by the success of the agricultural research effort. The tasks of research are to recognise which factors are currently constraining the upward shift in yield, and to overcome these. The range of farm yields show that even without major constraints upon performance, there were still other minor factors[4] that blocked many farmers from achieving MFY and maximum profit, which, if remedied, could lead to significant increases in productivity levels and returns, and could substantially improve the performance of the HYVP. From a policy viewpoint, extension provides the most scope for improvement, for it was shown that a lack of precise knowledge of the new technology was primarily responsible for the differences between actual yields and the MFY, i.e.,

4 However, it is acknowledged that the exploring of the factors affecting the performance of the HYVP has been a partial success in this study.

the farmer yield gap. By transmitting information quickly and accurately to farmers, an effective extension service can minimise this gap.

The lack of serious external constraints, including risk, allowed farmers freedom of decision-making, and their performances served to demonstrate that they will attempt to maximise profits where possible, regardless of farm size. This means that under these circumstances, lack of motivation of farmers can be discounted as a factor detracting from the performance of the HYVP. The study also showed that the provision of institutional services to small farmers that provides them with opportunities similar to those enjoyed by large farmers and thus access to similar benefits is feasible, though further investigation into precisely how this was achieved is needed if policy implications are to be derived.

Because the technology proved neutral to size, and farmers gained equal access to inputs required for it, there was no worsening of the existing pattern of the distribution of benefits. Such inequities as there are in the distribution of income were independent of the technology and would have to be remedied by other government policies which for example, might modify the existing ownership pattern of land-holdings.

Finally, the analysis demonstrated the need for and potential benefits from, a sustained commitment to research, particularly in relation to the evolution of LSVs. Even in a leading area such as Coimbatore where research has already produced LSVs and led to a rise in productivity and farm income, the limits of that progress and the further research tasks were clearly evident. There was a lack of an LSV for rabi season that out-performed the EVs. A short duration LSV for this season could possibly alter the whole cropping system, from 2 to 3 crops annually. Second, there was still a need for an LSV for kharif season that was actually resistant to the main pests and diseases, especially the brown plant hopper.

APPENDIX 2.1

BACKGROUND SCHEDULE

Project ID
Village ID
Farmer ID
Schedule ID

1. Name of the Farmer: ....
   (Head of the household)

   Address: House No.: ....

   Street Name: ....

2. Age: ....

3. Literacy:
   a) Know how to read and write
   b) High School
   c) Higher Education
   d) Illiterate

4. Type of House:
   a) Mud
   b) Brick
   c) Stone

5. Family Characteristics:

   a) Those living with the head in the House:

S.No.	Relation to head	Age	Sex	Literacy	Occupation
1					
2					
3					
4					

6. Area Operated this year (in acres):

		Kharif Season
a) area owned		
b) area leased in	(+)	
c) area leased out	(-)	
Total operational holding		

7. Cropping Pattern - last year (acres)

Sl.No.	Crop	HYV NHYV	Variety Name	Area devoted Kharif	Area devoted Rabi

APPENDIX 2.1 (Cont'd)

Page 2.

8. History of HYV growing:

a) When did you first grow HYVs in

i) Kharif season ....

ii) Rabi season ....

b) Which varieties

i) Kharif ....

ii) Rabi ....

c) Have you grown HYV continuously each year since then?

i) Kharif .... ii) Rabi ....

d) If no, why not? ....

....

e) Have you changed the varieties of HYVs?

i) Kharif .... ii) Rabi ....

f) If so, what were the changes?

i) Kharif ....

ii) Rabi ....

g) Why did you make these changes (Note each change and reasons).

....

....

9. Inventory - this year

Q.No.	S.No.	Description Type	Total Nos.	Date of Purchase	Purchase Cost	Used for HYVs			Present value.	Expected life.
						Wholly 1	Partly 2	Not at all 3		
	1	Tractor...								
	2	Bullocks								
	3	Ploughs								
	4	Shovels								
		Baskets								
		Crow Bar								
		Sickle								
	5	Sprays								
	6	Cart								

10. Irrigation - this year

a) Types:

1. Canal; 2. River lift; 3. Tank; 4. Well

APPENDIX 2.1 (Cont'd)

Page 3.

11. Credit - last year.

a) Did you obtain loans for paddy cropping last year?

	HYV		NHYV	
	Kharif	Rabi	Kharif	Rabi
1. Yes.				
2. No.				

b) If yes, the source of borrowing?

	HYV		NHYV	
	Kharif	Rabi	Kharif	Rabi
1. Relatives				
2. Friends				
3. Co-operatives				
4. Private Traders				
5. Money lenders				
6. Landlord				

c) Did you repay your last years loans?

1) Yes   2) No

d) If no, how much do you still owe and to whom?

12. Distance. What is the distance travelled by you from your house to:

a) get seeds?

b) get fertilisers?

c) get plant protection chemicals?

Page 4.

APPENDIX 2.1 (Cont'd)

13. <u>Disposal of paddy - Last year</u>

Q.No.	S.No.	HYV NHYV	Variety Name	Total Output		Amount given in kind as wages		Amount given in kind to landlord		Amount Sold		The Name of Purchaser		Amount Retained	
				K	R	Kharif	Rabi	K	R	K	R	Kharif	Rabi	Kharif	Rabi

APPENDIX 2.1 (Cont'd)

Page 5.

14. Extension Contact:

a) During last year were you visited by extension officials?

		Kharif	Rabi
i)	Yes		
ii)	No.		

b) If yes, who visited you and how many times?

S.No.	Personnel	Kharif	Rabi
1	V.L.W.		
2	B.D.O.		
3	A.E.O.		
4	Others (specify)		

1) Once a fortnight
2) Once a month
3) Once in two months
4) Once in a season.

c) Did they give advice on HYVs on visits? If yes, say the number of advices?

d) Did you seek advice yourself on any matters regarding the cultivation of HYV paddy?

i) Yes
ii) No.

e) If yes, from whom did you get technical information about HYV paddy?

1) Relatives
2) Neighbours and friends
3) Extension Officials
4) Traders
5) Radio
6) Others (Specify)

15. Tax:

a) Do you pay any taxes on Land?
i) Yes ii) No.

b) If yes, which are they? ....

....

c) How much did you pay last year?

d) Do you know on what basis they are levied?

16. Farm Income:

S.No.	Crop	Income Received		Total value of sales		Remarks
		Kharif	Rabi	Kharif	Rabi	

17. Non-Farm Income: (Those living with household head)

S.No.	Relation to head	Type of work		Amount received	
		Kharif	Rabi	Kharif	Rabi

APPENDIX 2.2

FARMER SCHEDULE
(Quantitative)

Project ID
Village ID
Farmer ID
Season ID
Schedule ID

Season:

1. Name of the Farmer: ....

Address: ....

....

A. Cropping Pattern

2. Operational Holding: (in hect.)

	TOTAL	IRRIGATED
(a) Owned		
(b) leased in (+)		
(c) leased out (-)		

3. Land Use

Q.No.	S.No.	Crop	HYV-I NHYV-2	Name of variety	Number of fields	Area Total (hect.)				
						Cropped	Fallow	Grazing		

APPENDIX 2.2 (Cont'd)

Page 2.

B. PADDY ACTIVITIES AND INPUTS

4. Labour Inputs:

Sl.No.	HYV NHYV	Variety Name	Field No.	Area	Activity	Date Performed	Total Days Worked: Family			Total Days Worked: Hired			Wage per Person			Total Wage Paid
							M	F	C	M	F	C	M	F	C	

5. Animal Power/Equipment Use:

Sl.No.	HYV NHYV	Field No.	Area	Activity	Items	Date Performed	Total Days Worked: Owned	Total Days Worked: Hired	Price Paid per Day	Total Cost

6. Inputs - Seeds (Paddy)

Sl.No.	Field No.	Area	HYV NHYV	Variety Name	Seed Source	Seeding Rate/hect.: Actual	Seeding Rate/hect.: Recom.	Seeding Rate/hect.: O.Norm	Price/ Kg.	Total Cost

APPENDIX 2.2 (Cont'd)

Page 3.

7. Fertiliser:

Sl.No.	Field No.	Area	Ferti-liser Name	Fertiliser Type S	M	C	HYV NHYV	Variety Name	Source Purchase	Application Rate BASAL Act	Rec	On	TOP DRESSING Ac	R	On	Price/ Kg.	Total Cost

8. Water:

Sl.No.	Field No.	Area	HYV NHYV	Variety Name	Sources	Times of Application	Depth of Application	Evenness of Application

9. Plant Protection:

Sl.No.	Field No.	Area	Purpose	HYV NHYV	Variety Name	Problems	Type Used	Application Rate Actual	Recom	Timing	Price/ Unit	Total Cost

APPENDIX 2.2 (Cont'd)

Page 4.

10. Output: (in Kgs.)

Sl.No.	Field No.	Area	HYV NHYV	Variety Name	Harvest Days	Area Harvested (hect.)	Total Output	Yield/ Acre

11. Harvest Disposal:

Sl.No.	Field No.	Area	HYV NHYV	Variety Name	Amount Given in Kind		Retained For	
					Labourers	Land Lord	Seeds	Consumption

Sales			Price/ Kg.	Total Value of Sales	Amount Actually Received	Amount Retained By the Trader for Loans
Date of Sale	Name of Purchaser	Amount Sold				

APPENDIX 2.2 (Cont'd)

Page 5.

12. Credit:

Sl.No.	Credit Source	Amount Borrowed	Loans Used For	Purpose	Rate of Interest	Timeliness of Loans	Adequacy of Loans

13. If further credit was available to you on favourable conditions, on which items will you spend it?

Sl.No.	Items	Amount		Comments
		HYV	NHYV	
1	Seeds			
2	Organic fertiliser			
3	Chemical fertiliser			
4	Plant protection			
5	Equipments			
6	Labour			
7	Others (specify)			

APPENDIX 2.3

DECISION AND OPINION SCHEDULE
(Qualitative)

Project ID
Village ID
Farmer ID
Season ID

Season:

1. Name of the Farmer: ....
Address: ....
....

2. Tenurial Conditions: (A) Leasing in:

i) Why do you lease in land?

ii) What do you use this land for?

1. Paddy 2. Turmeric 3. Sugar Cane 4. Banana ( )

iii) If paddy, do you use it for HYVs?

1. Yes 2. No ( )

iv) If not, why not?

v) What is the nature of lease?

1. Oral 2. Written ( )

1. by season 2. Year 3. Longer term ( )

vi) Do you share the inputs with the lessee?

1. Yes 2. No ( )

vii) If yes, how much and what are they?

viii) What are the payment arrangements? ( )

1. Proportion of output 2. Fixed quantity of output

2. Proportion of gross income 4. Fixed part of gross income

ix) Have the input and payment arrangements affected

a) Your decision to use HYVs or not? 1. Yes 2. No ( )

If yes how?

b) the level of inputs you apply to the HYVs?

1. Yes 2. No ( )

If yes in what ways?

APPENDIX 2.3 (Cont'd)

Page 2.

(B) Leasing out:

i) Why do you lease out land?

ii) What is it used for?

1. Paddy 2. Turmeric 3. Sugar Cane 4. Banana ( )

iii) Do you have any influence over this?

1. Yes 2. No ( )

If yes, what?

iv) Do you share inputs with the lessee?

1. Yes 2. No ( )

If yes, in what ways?

v) What are the arrangements for payment? ( )

1. Proportion of output 2. Fixed quantity of output

3. Proportion of gross income 4. Fixed part of gross income

3. Cropping Pattern (A) - All Crops

i) What made you decide to plant the crops shown in this season?

ii) Did others influence you in your decisions on crops and crop areas? 1. Yes 2. No ( )

iii) If yes, who are they? ( )

1. Relatives 2. Neighbours and Friends

3. Extension Officials 4. Others

iv) Are there any official recommendations of crops for this season? 1. Yes 2. No ( )

v) If yes, what are they?

vi) Do you agree with them? 1. Yes 2. No ( )

vii) If not, why not?

APPENDIX 2.3 (Cont'd)

Page 3.

viii) Did your adoption of HYVs lead to any change in the cropping pattern? 1. Yes 2. No ( )

ix) If yes, in which season? 1. Kharif 2. Rabi ( )

x) What was the change?

xi) Why did you make it?

(B) HYV Paddy

i) Why did you choose these varieties for this season?

ii) What HYVs are officially recommended for this season?

iii) How do you know this? ( )

1. Relatives 2. Neighbours & Friends

3. Extension Officials 4. Traders 5. Radio

6. Discussion Group 7. Experiment Station

iv) Do you agree with these recommendations? 1. Yes 2. No ( )

v) If not, why not?

vi) Do you still have any problems with the HYVs?

1. Yes 2. No ( )

vii) If yes, what are they?

(C) Non-HYV Paddy (both local improved and local varieties):

i) Why did you choose these varieties for this season?

ii) How did you decide the area under non-HYVs?

iii) Is there any official recommendation about the non HYV?

1. Yes 2. No ( )

iv) If yes, did this influence your decision?

1. Yes 2. No ( )

APPENDIX 2.3 (Cont'd)

Page 4.

v) If no, why did you decide otherwise?

vi) Do these non-HYVs have any characteristics superior to HYVs? 1. Yes 2. No ( )

vii) If yes, what are they?

4. Paddy Cultivation Practices:

i) Do you know the recommendations of the following:

			HYV	NHYV
a) Nursery preparation	1. Yes	2. No	( )	( )
b) Seed and Seed treatment	"	"	( )	( )
c) Paddy field preparations	"	"	( )	( )
d) Transplanting	"	"	( )	( )
e) Weeding	"	"	( )	( )

Note: If the farmer says, yes, he is asked to explain briefly the recommendations. This enables us to compare the recommendations with their answer to judge their answer.

ii) Do you follow them?

1. Yes 2. Not all 3. Not at all ( )

iii) If not, why not?

iv) Do you find any basic difference in the cultural practices you are following for HYVs from the ones you are/were following by NHYVs?

1. lot of 2. little 3. Nil ( )

v) If yes, what are they?

5. Watering:

i) Do you find much uncertainty about the onset of rainfall in this season? 1. Yes 2. No ( )

ii) Do you organise your nursery and field preparations according to the start of the monsoon?

1. Yes 2. No ( )

iii) If no, do you use a source of irrigation for this?

1. Yes 2. No ( )

APPENDIX 2.3 (Cont'd)

Page 5.

iv) If yes, which source?

v) Do the monsoon onset and strength subsequently affect the yields of HYVs? 1. Yes 2. No. ( )

vi) If yes, what has been your experience of the yields range with variations in rainfall?

vii) Do you receive enough water, when you want it at the beginning of this season? 1. Yes 2. No. ( )

If not, why not?

viii) Does this affect the area of paddy or of HYVs you decide to plant? 1. Yes 2. No ( )

ix) If yes, how?

x) Does this affect your nursery and field preparation?

1. Yes 2. No ( )

xi) If yes, how?

xii) Are you sure of having enough and timely water as needed during this season? 1. Yes 2. No ( )

xiii) If not, why not?

xiv) Do you adjust your inputs/field practices according to availability of water? 1. Yes 2. No ( )

xv) If yes, what ways?

xvi) If you had a dependable and adequate water supply would you

- increase your HYV area? 1. Yes 2. No ( )
- increase your levels of fertilisers 1. Yes 2. No ( )
- change your field practices 1. Yes 2. No ( )

xvii) Do you have any special problem with irrigation supplies because of the location of your fields?

1. Yes 2. No ( )

APPENDIX 2.3 (Cont'd)

Page 6.

xviii) If yes, which fields and what problems?

xix) Does it affect your practices? 1. Yes 2. No ( )

( )

xx) If your fields received enough and regular water supplies, would you change any practices?

1. Yes 2. No ( )

xxi) If yes, which and how?

xxii) Have your irrigation supplies improved since the introduction of HYVs? 1. Yes 2. No ( )

xxiii) If yes, how?

xxiv) Do you have any special problems with irrigations because of the characteristics of your fields?

1. Yes 2. No ( )

xxv) If yes, which fields and what problems?

xxvi) Does it affect your practices? 1. Yes 2. No ( )

xxvii) Do these problems (xvii and xxiv) affect yields? 1. Yes 2. No ( )

xxviii) If yes, by how much usually according to your calculations?

xxix) Do you see any possibility of improving the regular water supply? 1. Yes 2. No ( )

xxx) If yes, how?

(e.g.) construction of canals, investments on groundnutwater etc.

6. Fertilisation: (A) General:

i) Have your soils been tested? 1. Yes 2. No ( )

ii) If yes, when?

iii) What were the results by soil type? N
P
K

APPENDIX 2.3 (Cont'd)

Page 7.

iv) If no, why not?

v) How do you know what fertiliser is needed?

(B) Nitrogen Fertilisers:

i) What kind of fertiliser do you prefer? ( )

1. Straight 2. Mixture 3. Complex 4. No preference

ii) If preferred, how do you do so?

iii) How do you decide on your dosage?

iv) Do you have a preferred dosage (own norm) for HYVs in basal and top dressing? 1. Yes 2. No ( )

v) Is there any difference between your norm and your actual application?

	Basal	Topdressing
1. Yes 2. No	( )	( )

vi) If yes, how much and why?

vii) Is there any difference between your norm and recommendation in basal and top dressings? 1. Yes 2. No ( )

viii) If yes, how much and why?

ix) Are you able to get timely supplies in this season?

1. Yes 2. No ( )

x) If not, why not?

xi) Has it affected your dosages? If so, by how much? ( )

1. Yes 2. No

xii) Are you able to get adequate supplies in this season?

1. Yes 2. No ( )

xiii) If not, why not?

xiv) Has it affected your dosages? If so by how much?

1. Yes 2. No ( )

APPENDIX 2.3 (Cont'd)

Page 8.

xv) Are you able to obtain your preferred type?
1. Yes 2. No ( )

xvi) If not, why not?

xvii) Has it affected your dosages? 1. Yes 2. No ( )

xviii) If yes, how much?

xix) If there a control price for nitrogen? 1. Yes 2. No ( )

xx) If yes, what is it?

xxi) What prices have you paid? If higher, why?

xxii) Do you purchase nitrogen fertiliser by
(1) Cash (2) Credit (3) Both ( )

xxiii) If you purchased on credit, was there any limit on your purchases? If so, how much?

xxiv) Why was there a limit?

(C) Organic Manures:

i) How do you decide on your dosage?

ii) Do you have a preferred dosage for HYVs? 1. Yes 2. No ( )

iii) What are the official recommendations for HYVs?

iv) Do you follow them? 1. Yes 2. No ( )

v) If not, why not?

vi) Do you use inorganic fertilisers for organic manures?
1. Yes 2. No ( )

vii) If yes, why?

viii) Did you seek technical advice on this? 1. Yes 2. No ( )

APPENDIX 2.3 (Cont'd)

Page 9.

ix) If yes, from whom?

1. Extension officials 2. Neighbours & Friends

3. Traders (4) Experiment station 5. Others ( )

7. Plant Protection:

i) Do you use chemicals to prevent pests and diseases?

1. Preventive 2. Curative 3. Both ( )

ii) How do you decide whether to treat pests and diseases?

1. Own decision 2. Neighbours & Friends

3. Official persuation ( )

iii) Are you able to get in this season

a. Timely supplies 1. Yes 2. No ( )

b. Adequate supplies " " ( )

c. Preferred type " " ( )

iv) If not, why not?

v) Have extension officials advised you about treatment this season? 1. Yes 2. No ( )

vi) Was this at your request? 1. Yes 2. No ( )

vii) How do you purchase plant protection chemicals?

1. Cash 2. Credit 3. Both ( )

8. Credit:

i) Which source do you prefer to borrow?

1. Cooperatives 2. Relatives 3. Neighbours & Friends

4. Money lenders 5. Traders 6. Landlord ( )

ii) Can you obtain enough credit from them? 1. Yes 2. No ( )

iii) If not, why not?

iv) Does the cost of credit affect your input decisions?

1. Yes 2. No ( )

v) If yes, how?

vi) Does the amount of available credit affect your input decisions? 1. Yes 2. No ( )

vii) If yes, how?

APPENDIX 2.3 (Cont'd)

Page 10.

viii) Does the timing of credit availability affect your input decisions? 1. Yes 2. No ( )

ix) If yes, how?

9. <u>Harvesting</u>:

i) How do you thresh the output (paddy)? ( )

1. Mechanical 2. Bullocks 3. Hands

ii) What kind of storage facilities do you have?

1. Own 2. Rented 3. Leased 4. Own and rented

5. Own and leased 6. Rent and leased ( )

iii) What type of facility do you use?

1. Mud 2. Bricks 3. Stone ( )

iv) What is the capacity of storing room?

v) Is it adequate? 1. Yes 2. No ( )

vi) If not, does this influence your marketing? 1.Yes 2. No ( )

How?

vii) Are there any storage losses? If so how much? Why?

viii) How long do you store the output?

ix) Does it affect your sale price? 1. Yes 2. No ( )

10. <u>Marketing</u>:

i) How do you decide when you sell?

ii) How do you decide to whom you sell?

iii) Are you satisfied with this marketing? 1. Yes 2. No ( )

iv) If not, why not?

11. <u>Expectations</u>:

i) What is your expected price for paddy this season?

1. HYV ( )

2. NHYV( )

APPENDIX 2.3 (Cont'd)

Page 11.

ii) Do you expect prices this season to follow last year prices? 1. Yes 2. No ( )

iii) If not, why not?

iv) Will it differ between HYV and NHYV? 1. Yes 2. No ( )

v) Do you vary your fertiliser dosage according to your paddy price expectations? 1. Yes 2. No ( )

vi) If yes, to what extent?

vii) If no, why not?

viii) Is there much difference between your expectation and actual price you received in the last kharif season?

1. Yes 2. No ( )

ix) If yes, why?

x) Do you know the yield rate in nearest experimental station/field demonstration plots for the varieties you are growing? 1. Yes 2. No ( )
( )

xi) Do you know why you are not obtaining that yield?

1. Yes 2. No ( )

xii) If yes, what?

xiii) Do you form any expectations of likely yields before planting paddy and applying fertilisers?

1. Yes 2. No ( )

xiv) If yes what is your expected yield in this season?

a. Maximum ( )

b. Minimum ( )

c. Average ( )

xv) Do these expectations affect the area you plant to HYVs?

1. Yes 2. No ( )

xvi) If yes, in what ways?

APPENDIX 2.3 (Cont'd)

Page 12.

xvii) Do they affect the choice of HYVs? If so, how?

a. Timing of operations	1. Yes	2. No	( )
b. Practices you use	"	"	( )
c. Dosage of fertilisers	"	"	( )

xviii) Which, whether HYV or NHYV has more variations in yield, according to your experience.

Note: Questions in these sections will be asked in the beginning, in between and at the end of the season.

APPENDIX 2.4

ACTIVITY SCHEDULE

A. Labour Inputs:

Sl.No.	HYV - 1 NHYV - 2	Variety Name	Field No.	Area	Activity	Date Performed	Total Hours Worked: Family			Total Hours Worked: Hired			Wage per Persons (Rs.)			Total Wage Paid (Rs.)
							M	F	C	M	F	C	M	F	C	

B. Animal Power/Equipment Use:

Sl.No.	HYV - 1 NHYV - 2	Field No.	Area	Variety Name	Activity	Items Used	Date Performed	Total Hours Worked: Owned	Total Hours Worked: Hired	Price Paid per Hour (Rs.)	Total Cost (Rs.)

APPENDIX 2.5

AVERAGE INPUT APPLICATIONS TO HYVS BY SAMPLE OWNER AND TENANT CULTIVATORS, KHARIF SEASON, 1977

Inputs/Farm Characteristics	Average Application per acre		
	Owner	Tenant	T-value
Sample Size	79	12	
Hired Labour (Man-days)	190.31	184.86	0.98
Expenditure on Pesticides application (Rs.)	165.26	182.35	1.01
Expenditure on other inputs (Rs.)	325.18	300.96	0.52
Nitrogenous Fertiliers (Kgs.)	46.23	45.87	0.31
Phosphatic Fertiliers (Kgs)	21.85	22.54	0.67
Potassic Fertiliser (Kgs.)	22.02	21.05	0.97
Yield (ton)	2.03	1.99	0.21

AVERAGE INPUT APPLICATIONS TO HYVS BY SAMPLE OWNER AND TENANT CULTIVATORS, RABI SEASON, 1977-8

Inputs/Farm Characteristics	Average Application per acre		
	Owner	Tenant	T-value
Sample Size	81	10	
Hired Labour (Man-days)	188.23	189.36	0.61
Expenditure on Pesticides application (Rs.)	100.56	82.17	1.32
Expenditure on other inputs (Rs.)	240.10	215.36	1.57
Nitrogenous Fertiliser (Kgs.)	42.00	41.26	0.52
Phosphatic Fertiliser (Kgs.)	18.03	18.62	0.21
Potassic Fertiliser (Kgs.)	20.10	19.20	0.72
Yield (ton)	1.46	1.40	0.49

APPENDIX 3.1

1. The density function for y_i in (3.22) depends on the density function of ε_i by the following identity:

$$f_y(y_i) = f_\varepsilon(y_i - x_i\beta) \tag{1}$$

where $f_\varepsilon(\cdot)$ represents the density function of ε_i.

It may be recalled from (3.21) that the density functions of u_i and v_i respectively are:

$$f_u(u_i) = \frac{1}{\sigma_u\sqrt{1/2\ \pi}} e^{-\frac{1}{2}\frac{u_i^2}{\sigma_u^2}} \quad \text{if } u_i \leq 0 \tag{2}$$

$$= 0 \quad \text{otherwise}$$

$$f_v(v_i) = \frac{1}{\sigma_v\sqrt{2\pi}} e^{-\frac{1}{2}\frac{v_i^2}{\sigma_v^2}} \qquad -\infty < v_i < \infty \tag{3}$$

Now, the density function of ε_i which is the sum of a symmetric normal random variable (v_i) and a truncated normal random variable (u_i) can be defined as:

$$f_\varepsilon(\varepsilon_i) = \int_{-\infty}^{\infty} \psi_v\ (w)\ \psi_u(\varepsilon_i - w)\,dw, \qquad -\infty < \varepsilon_i < \infty$$

$$= \int_{e_i}^{\infty} \frac{1}{\pi\sigma_u\sigma_v} e^{\{-\frac{1}{2}[\frac{w^2}{\sigma_v^2} + \frac{(e_i - w)^2}{\sigma_u^2}]\}}\, d_w \tag{4}$$

Now considering only the terms within the square brackets,

$$\frac{w^2}{\sigma_v^2} + \frac{(e_i - w)^2}{\sigma_u^2} = \frac{w^2}{\sigma_v^2} + \frac{e_i^2 + w^2 - 2e_i w}{\sigma_u^2}$$

$$= \frac{w^2\sigma_u^2 + e_i^2\,\sigma_v^2 + w^2\sigma_v^2 - 2e_i w\sigma_v^2}{\sigma_u^2\,\sigma_v^2}$$

$$= \frac{w^2(\sigma_u^2 + \sigma_v^2) + e_i^2\,\sigma_v^2 - 2e_i w\sigma_v^2}{\sigma_u^2\,\sigma_v^2}$$

$$= \frac{w^2\sigma^2 + e_i^2\sigma_v^2 - 2e_i w\sigma_v^2}{\sigma_u^2\,\sigma_v^2} \quad (\because\ \sigma^2=\sigma_u^2 + \sigma_v^2)$$

$$= \frac{(w^2 + e_i^2\,\sigma_v^2/\sigma^2 - 2e_i w\sigma_v^2/\sigma^2)\ \sigma^2}{\sigma_u^2\,\sigma_v^2}$$

$$= \left[\left(w-\frac{e_i\sigma_v^2}{\sigma^2}\right)^2 + e_i^2\ \frac{\sigma_v^2}{\sigma^2} - \frac{e_i^2\sigma_v^4}{\sigma^4}\right]\left(\frac{\sigma^2}{\sigma_u^2\sigma_v^2}\right)$$

$$=\left(w-\frac{e_i\sigma_v^2}{\sigma^2}\right)^2\left(\frac{\sigma^2}{\sigma_u^2\sigma_v^2}\right) + \left[\left(1-\frac{\sigma_v^2}{\sigma^2}\right)\frac{(e_i^2\ \sigma_v^2)}{\sigma^2}\right]\frac{\sigma^2}{\sigma_u^2\sigma_v^2}$$

$$=\left(w-\frac{e_i\sigma_v^2}{\sigma^2}\right)^2\left(\frac{\sigma^2}{\sigma_u^2\sigma_v^2}\right) + \left(\frac{\sigma^2-\sigma_v^2}{\sigma^2}\right)\left(\frac{e_i^2\sigma_v^2}{\sigma^2}\right)\left(\frac{\sigma^2}{\sigma_u^2\sigma_v^2}\right)$$

$$=\left(w-\frac{e_i\sigma_v^2}{\sigma^2}\right)^2\left(\frac{\sigma^2}{\sigma_u^2\sigma_v^2}\right) + \left(\frac{e_i^2}{\sigma^2}\right)$$

$$\therefore\ \frac{w^2}{\sigma_v^2} + \frac{(e_i-w)^2}{\sigma_u^2} = s^2 + \frac{e_i^2}{\sigma^2} \quad \text{where} \quad s = \left(w-\frac{e_i\sigma_v^2}{\sigma^2}\right)\left(\frac{\sigma}{\sigma_u\sigma_v}\right) \tag{5}$$

Now, $\quad ds = dw\ \dfrac{\sigma}{\sigma_u\sigma_v}$

$\therefore\quad dw = \dfrac{\sigma_u\sigma_v}{\sigma}\ .\ ds$

Now (4) $\displaystyle = \int_{e_i^*}^{\infty} \frac{1}{\pi\sigma_u\sigma_v}\, e^{[-\frac{1}{2}(s^2 + e_i^2/\sigma^2)]} ds\ \frac{\sigma_u\sigma_v}{\sigma}$ where $e_i^* = \dfrac{e_i\sigma_u}{\sigma\sigma_v}$

$$= \frac{1}{\pi\sigma} e^{-\frac{1}{2}\frac{e_i^2}{\sigma^2}} \int_{e_i^*}^{\infty} e^{-\frac{1}{2} \cdot s^2} ds$$

$$= \frac{1}{\sigma\sqrt{1/2\,\pi}} e^{-\frac{1}{2}\frac{e_i^2}{\sigma^2}} \int_{e_i^*}^{\infty} \frac{1}{\sqrt{1/2\pi}} e^{-\frac{1}{2}s^2} ds$$

∴ The density function of ε_i,

$$f_\varepsilon(\varepsilon_i) = \frac{1}{\sigma\sqrt{1/2\,\pi}} e^{-\frac{1}{2}\frac{e_i^2}{\sigma^2}} [1-F(e_i\sigma_u/\sigma\sigma_v)] \qquad (6)$$

where $F(\cdot)$ is the cumulative distribution function of the standard normal random variable. Defining, $\gamma = \frac{\sigma_u^2}{\sigma_u^2 + \sigma_v^2}$ and substituting γ in the distribution function $F(\cdot)$ above, we get,

$$f_\varepsilon(\varepsilon_i) = \frac{1}{\sigma\sqrt{1/2\,\pi}} e^{-\frac{1}{2}\frac{e_i^2}{\sigma^2}} [1-F(e_i \frac{\gamma}{1-\gamma})] \qquad (7)$$

The density functions of y_i is obtained by substituting,

$$y_i = x_i\beta + e_i \text{ in (6)}$$

$$\text{i.e., } f_y(y_i) = \frac{1}{\sigma\sqrt{1/2\,\pi}} e^{-\frac{1}{2}\frac{(y_i-x_i\beta)^2}{\sigma^2}} [1-F\{y_i-x_i\beta)(\frac{\gamma}{1-\gamma})\}] \qquad (8)$$

where $\gamma = \frac{\sigma_u^2}{\sigma_u^2 + \sigma_v^2}$

2. The expected value and variance of y_i are given as:

$$E(y_i) = x_i\beta + E(u_i) + E(v_i) \qquad (9)$$

and $V(y_i) = Var\ (u_i) + Var\ (v_i)$ (10)

now (9) $= x_i\beta + E(u_i)$, as $E(v_i) = 0$

consider only $E(u_i) = \int_{-\infty}^{0} u \frac{1}{\sigma_u \sqrt{1/2\, \pi}} e^{-\frac{1}{2}\frac{u^2}{\sigma_u^2}} du$ (11)

Let $\frac{1}{2}\frac{u^2}{\sigma_u^2} = t$ (12)

$\therefore u\, du = \sigma_u^2\, dt$

Substituting (12) in (11), we get

$$E(u_i) = \int_{\infty}^{0} \frac{1}{\sigma_u \sqrt{1/2\, \pi}} e^{-t} \sigma_u^2\, dt.$$

$$= \frac{\sigma_u}{\sqrt{1/2\, \pi}} \int_{\infty}^{0} e^{-t}\, dt.$$

$$= -\sigma_u \sqrt{\frac{2}{\pi}} \int_{0}^{\infty} e^{-t}\, dt.$$

$$\therefore E(u_i) = -\sigma_u \sqrt{\frac{2}{\pi}}.$$

$$\therefore E(y_i) = x_i\beta - \sigma_u \sqrt{\frac{2}{\pi}} \tag{13}$$

$$= x_i\beta - \sigma \sqrt{\frac{2\gamma}{\pi}} \quad \text{where, } \gamma = \frac{\sigma_u^2}{\sigma_u^2 + \sigma_v^2}$$

In (10) $\quad Var\ (v_i) = \sigma_v^2$

$$Var\ (u_i) = E(u_i^2) - [E(u_i)]^2$$

$$\text{Now}\quad E(u_i^2) = \int_{-\infty}^{0} u^2 \frac{1}{\sigma_u\sqrt{1/2\,\pi}} e^{-\frac{1}{2}\frac{u_i^2}{\sigma_u^2}}\,du.$$

$$= 1/2 \int_{-\infty}^{\infty} u^2 \frac{1}{\sigma_u\sqrt{1/2\,\pi}} e^{-\frac{1}{2}\frac{u^2}{\sigma_u^2}}\,du. \qquad \text{(Since,}$$

$f(u) = u^2 . e^{-\frac{1}{2}\frac{u^2}{\sigma_u^2}}$, $-\infty<u<\infty$, is symmetric about the print u=0).

$$\therefore \quad E(u_i^2) = \int_{-\infty}^{\infty} \frac{1}{\sigma_u\sqrt{2\pi}} u^2 e^{-\frac{1}{2}\frac{u^2}{\sigma_u^2}}\,du.$$

This is analogous to the expectation of the square of a normal random variable $N(O,\sigma_u^2)$.

$$\therefore E(u_i^2) = \sigma_u^2.$$

$$\therefore \quad \text{Var}\ (u_i) = \sigma_u^2 - [-\sigma_u\sqrt{\tfrac{2}{\pi}}.]^2$$

$$= \sigma_u^2 - \sigma_u^2 \frac{2}{\pi}$$

$$= \sigma_u^2\ (\pi-2)/\pi$$

$$\therefore \quad \text{Var}\ (y_i) = \sigma_v^2 + \sigma_u^2\ (\pi-2)/\pi$$

$$= \sigma^2 - \sigma_u^2 + \sigma_u^2\ (\pi-2)/\pi$$

$$\therefore \quad \text{Var}\ (y_i) = \sigma^2\ (\pi-2\gamma)/\pi \qquad (14)$$

APPENDIX 3.2

Estimation of Profit Function and Variable Factor Demand Functions:

Theil has argued that the conventional approach of formulating and estimating models without incorporating *a priori* information supplied by economic theory on the parameters is inadequate, and that efficiency of estimation can be increased by imposing known restrictions on the coefficients in the models.[1] In the context of the profit function and variable factor demand functions, the same predetermined variables, namely, prices, land and capital are used as regressors. The determined variables in the equations are jointly dependent variables because of the profit identity $[\pi = P_Y Y - \sum_{i=1}^{m} p_i x_i]$ and also the farm's decision variables, in the short run, are the profit and variable factor costs. For convenience the profit and variable factor demand functions are recalled here from (3.39) and (3.42)

$$\ln \pi^* = \ln A^* + \sum_{i=1}^{4} \beta_i^* \ln r_i + \sum_{i=1}^{2} \alpha_i^* \ln Z_i \qquad (1)$$

$$-\frac{r_i \hat{x}_i}{\pi^*} = \beta_i^* \qquad i = 1,2,3,4 \qquad (2)$$

So the *a priori* information of β_i^* appearing in both (1) and (2) should not be ignored. The equations should be jointly estimated with the restrictions that β_i^*'s are equal. These constraints can be dealt with in two ways. One way is by estimating the equations without any restrictions and then

---

1 Theil, H. (1963) 'On the use of incomplete prior information in regression analysis', *Journal of American Statistical Association*, Vol.58 (pp.401-14).

testing the equality of the coefficients by using the statistic given by Johnston.[2] An alternative way is to incorporate the constraints in the estimation process itself, so that the estimated coefficients exactly satisfy the restrictions imposed by a priori information, which is adopted in the present study.

To estimate equations (1) and (2) under stochastic conditions, it becomes necessary to introduce disturbance terms in both (1) and (2). This can be done by assuming an additive error term to the profit and factor demand functions.

$$\ln \pi^* = \ln A^* + \Sigma\beta_i^* \ln r_i + \Sigma\alpha_i^* \ln A_i + u \tag{3}$$

$$-\frac{r_i \hat{x}_i}{\pi^*} = \beta_i^* + v \qquad i = 1,2,3,4 \tag{4}$$

where u represents unknown exogeneous factors like climate and weather conditions in (3) and v in (4) is divergence between expected and realised prices.[3] It is also assumed that:[4]

$$\begin{aligned} &E(u_i) = 0 ; \\ &\underset{i\neq j}{E} (u_i u_j) = 0 ; \quad \underset{i\neq j}{E} (v_i v_j) = 0 ; \\ &\underset{i=j}{E} (u_i u_j) = \sigma_u^2 \quad \text{and} \quad \underset{i\neq j}{E} (u_i v_j) \neq 0. \end{aligned} \tag{5}$$

---

2 Johnston, J. (1972) Econometric Methods, McGraw-Hill Kogakusha Ltd., Tokyo, (pp.152-6).

3 Lau, L.J. and P.A. Yotopoulos (1972) (p.15).

4 Yotopoulos, P.A. and L.J. Lau (1973) (p.219).

These error specifications (5), enable us to apply Aitken's generalised least squares (GLS) used by Zellner,[5] imposing the equality of β^* parameters in the equations showing profit and factor demand functions. This is an asymptotically efficient method of estimation. The equations are estimated as a system using a variant of GLS and the constraints on the β^* estimates were imposed by Lagrange multiplier, as proposed by Byron.[6]

The equations were arranged in the manner of Zellner's application of GLS with the constraints imposed by Lagrange multipliers, λ. Now the restricted objective function in general is,

$$\phi = (\pi - Z\beta)' \; \Omega^{-1}(\pi - Z\beta) - 2\lambda'(R\beta - r) \qquad (6)$$

where Z is an mn x m(m+1) observation matrix where as in the Zellner's model the x's were arranged in block diagonal form. π is an mn x 1 vector of dependent variables; R is a k x m(m+1) matrix of k restrictions on the coefficient vector; Ω refers to the contemporaneous covariance matrix of residuals; r is a (kx1) vector of constants associated with the constraints and λ is a (kx1) column vector of Lagrange multipliers used to impose the restrictions. The objective functions (6) have to be minimised with respect to β and λ and the results are as follows:

$$\frac{\partial\phi}{\partial\beta} = - 2\Omega^{-1}Z'\pi + 2(Z'\Omega^{-1}Z)\beta - 2R'\lambda = 0 \qquad (7)$$

$$\frac{\partial\phi}{\partial\lambda} = 2R\beta - 2r = 0 \qquad (8)$$

5 Zellner, A. (1962).

6 Byron, R.P. (1970).

Premultiplying (7) by $R(Z'\Omega^{-1}Z)^{-1}$ gives,

$$-R(Z'\Omega^{-1}Z)^{-1}\Omega^{-1}Z'\pi + R(Z'\Omega^{-1}Z)^{-1}(Z'\Omega^{-1}Z)\beta - R(Z'\Omega^{-1}Z)^{-1}R'\lambda = 0$$

i.e., $$-R\hat{\beta} + R\beta - R(Z'\Omega^{-1}Z)^{-1}R'\lambda = 0 \tag{9}$$

where $\hat{\beta}$ are the unrestricted OLS estimator

Hence, $$\tilde{\lambda} = [R(Z'\Omega^{-1}Z)^{-1}R']^{-1}\ (r-R\hat{\beta}) \tag{10}$$

$$\beta^* = \hat{\beta} + (Z'\Omega^{-1}Z)^{-1}R'[R(Z'\Omega^{-1}Z)^{-1}R']^{-1}(r-R\hat{\beta}) \tag{11}$$

where, β^* are the restricted estimates.

The standard errors of the β^* are derived from the covariance matrix,

$$\Sigma_{\hat{\beta}\hat{\beta}} = (Z'\Omega^{-1}Z)^{-1} - (Z'\Omega^{-1}Z)R'[R(Z'\Omega^{-1}Z)^{-1}R']^{-1}R(Z'\Omega^{-1}Z)^{-1} \tag{12}$$

where the second terms in LHS introduces the gain in the efficiency of point estimation due to a priori information.[7] It is possible with this approach, to test the individual restrictions, but its validity depends on the assumption that other restrictions are correct. The testing of the individual restrictions within the context of the complete set of restrictions is based on the linear relationship between the β and the λ which ensures that λ are asymptotically $N(0,\Sigma\lambda)$ where $\Sigma\lambda\lambda = [R(Z'\Omega^{-1}Z)^{-1}R']^{-1}$. Hence, when a particular λ is not statistically different from zero, this means that the restriction associated with it is satisfied. This implies, here, that the price efficiency parameters associated with that λ estimated from the profit function and the factor demand function are equal, with the assumption that other restrictions are correct.

---

7 Ibid., (p.819).

The testing of the overall restrictions is based on the Wald test statistic[8] which is written as:

$$(R\hat{\beta}-r)' \; [R(Z'\Omega^{-1}Z)^{-1}R']^{-1} \; (R\hat{\beta}-r)$$

i.e., $$(\hat{\beta}-\beta^*)' \; R' [R(Z' \; \Omega^{-1}Z)^{-1}R']^{-1} R(\hat{\beta}-\beta^*) \qquad (13)$$

from (10) and (11), $\hat{\beta}-\beta^* = - (Z' \Omega^{-1}Z)^{-1}R'\tilde{\lambda}$.

So, the test criterion reduces to $\tilde{\lambda}' R(Z' \Omega^{-1}Z)^{-1}R'\tilde{\lambda}'$ which is asymptotically χ^2 with k (no. of restrictions) degrees of freedom. When χ^2 differs significantly from zero, this means that the overall restrictions are not valid.

8 Wald, A. (1943) 'Tests of statistical hypotheses concerning several parameters when the number of observations is large', Transaction of the American Mathematical Society, Vol.45 (pp.426-82).

APPENDIX 3.3

ESTIMATED COBB-DOUGLAS PRODUCTION FUNCTION FOR SAMPLE PARTICIPANTS GROWING LSVs AND EVs IN KHARIF SEASON

Variable	Parameter
α (Constant)	0.5023** (0.1360)
Ln X_1 (Labour)	0.0923** (0.0417)
Ln X_2 (Fertiliser Application)	0.0658** (0.0324)
Ln X_3 (Capital Flow)	0.0314** (0.0152)
Ln X_4 (Other Inputs)	0.1073** (0.0497)
D_1 (Variety Dummy)	0.2592* (0.0401)
D_2 (BPH Control)	0.3126** (0.1498)

$\bar{R}^2 = 0.6841$

Notes: Figures in brackets are standard errors of estimates.

* significant at the 1% level.

** significant at the 5% level.

APPENDIX 3.4

ESTIMATED TRANSCENDENTAL TYPE PRODUCTION FUNCTION FOR SAMPLE PARTICIPANTS GROWING LSVs AND EVs IN KHARIF SEASON

Variable	Parameter
α (Constant)	0.6180** (0.2431)
Ln X_1 (Labour)	0.0490 (0.1091)
Ln X_2 (Fertiliser Application)	0.0743 (0.3232)
Ln X_3 (Capital Flow)	0.0112 (0.0084)
Ln X_4 (Other Inputs)	0.1626** (0.0880)
D_1 (Variety Dummy)	0.3893* (0.0428)
D_2 (BPH Control)	0.2545* (0.0414)
X_1	0.0008 (0.0009)
X_2	-0.0002 (0.0011)
X_3	-0.00008 (0.00024)
X_4	0.00001 (0.00002)
$\bar{R}^2 = 0.6571$	

Notes: Figures in brackets are standard errors of estimates.

* significant at the 1 per cent level.

** significant at the 10 per cent level.

APPENDIX 3.5

ESTIMATED QUADRATIC TYPE OF PRODUCTION FUNCTION FOR SAMPLE PARTICIPANTS GROWING LSVs AND EVs IN KHARIF SEASON

Variable	Parameter
Constant (α)	2.1167** (0.9864)
Labour ($\ln X_1$)	0.0032 (0.0024)
Fertiliser Application ($\ln X_2$)	0.0027 (0.0024)
Capital Flow ($\ln X_3$)	0.0209 (0.0024)
Other Inputs ($\ln X_4$)	0.0007 (0.0010)
BPH Control (D_2)	0.4338* (0.0746)
Variety Dummy (D_1)	0.7441* (0.0738)
X_{12}	0.00001 (0.00001)
X_{13}	-0.00001 (0.00001)
X_{14}	-0.00002 (0.00001)
X_{23}	0.000004 (0.00001)
X_{24}	0.00001 (0.00002)
X_{34}	-0.000001 (0.00001)
X_{11}	0.00001 (0.00001)
X_{22}	-0.000003 (0.00001)
X_{33}	0.000002 (0.00002)
X_{44}	-0.00002 (0.00002)
$\bar{R}^2 = 0.6754$	

Notes: Figures in brackets are standard errors.

* significant at the 1 per cent level.

APPENDIX 3.6

ESTIMATED TRANS-LOG TYPE OF PRODUCTION FUNCTION FOR SAMPLE PARTICIPANTS GROWING LSVs AND EVs IN KHARIF SEASON

Variable	Parameter
α (Constant)	0.8928** (0.4236)
Ln X_1 (Labour)	1.3432 (1.1163)
Ln X_2 (Fertiliser Application)	0.8855 (1.5570)
Ln X_3 (Capital Flow)	0.0201 (0.0019)
Ln X_4 (Other Inputs)	0.0645 (0.6388)
D_1 (Variety Dummy)	0.4082* (0.0415)
D_2 (BPH Control)	0.2340* (0.0450)
Ln X_{11}	0.2021** (0.0924)
Ln X_{12}	0.2739 (0.1470)
Ln X_{13}	-0.2145 (0.1197)
Ln X_{14}	0.1972 (0.1762)
Ln X_{22}	-0.6043 (0.3460)
Ln X_{23}	0.2058 (0.1875)
Ln X_{24}	0.1029 (0.1654)
Ln X_{33}	-0.0376 (0.1568)
Ln X_{34}	0.00278 (0.1901)
Ln X_{44}	0.00001 (0.00002)
$\bar{R}^2 = 0.6801$	

Notes: Figures in the brackets are standard errors of estimates.

* significant at the 1 per cent level.
** significant at the 5 per cent level.

APPENDIX 4.1

TESTS OF THE STABILITY OF SLOPE AND INTERCEPT BETWEEN EVs AND LIs USING AN ESTIMATED COBB-DOUGLAS PRODUCTION FUNCTION

Variables	Parameter
α (constant)	0.3961** (0.1869)
D_1 (Varietal dummy)	0.7623** (0.3768)
D_2 (BPH control)	0.1320** (0.0622)
D_{12} (Difference in D_2)	0.1208 (0.1572)
$\ln X_1$ (Labour)	0.1002 (0.0825)
$\ln X_2$ (Fertiliser application)	0.0789 (0.0538)
$\ln X_3$ (Capital flow)	0.1005** (0.0462)
$\ln X_4$ (Other inputs)	0.0921** (0.0428)
$D_1 \ln X_1$ (Difference in X_1)	-0.0785 (0.0816)
$D_2 \ln X_2$ (Difference in X_2)	-0.0345 (0.0531)
$D_3 \ln X_3$ (Difference in X_3)	0.0211 (0.0378)
$D_4 \ln X_4$ (Difference in X_4)	-0.0671 (0.0723)
$\bar{R}^2 = 0.7120$	

Notes: Figures in parentheses are standard errors of estimates.

** significant at the 5 per cent level.

BIBLIOGRAPHY

Aigner, D.J. and Chu, S.F. (1969). 'On estimating the industry production function', American Economic Review, Vol.58 (pp.826-38).

Aigner, D.J., Lovell, C.A.K. and P. Schmidt (1977). 'Formulation and estimation of stochastic frontier production function models', Journal of Econometrics, Vol.6 (pp.21-37).

Anderson, J.R. (1974). 'Risk efficiency in the interpretation of agricultural production research', Review of Marketing and Agricultural Economics, Vol.42, No.3 (pp.131-84).

Bardhan, P. (1970). 'Green revolution and agricultural labourers', Economic and Political Weekly, Vol.V, Nos. 29, 30 & 31 (pp.1239-46)

Barker, R. (1972). 'The economic consequences of the green revolution in Asia', in Rice, Science and Man, International Rice Research Institute, Los Banos, Philippines (pp.121-2).

Barker, R., Kauffman, H.E. and R.W. Herdt (1975). 'Production Constraints and Priorities for Research', paper presented at the International Rice Research Conference, IRRI, Los Banos, Philippines, April 21-25.

Battese, G.E. and G.S. Corra (1977). 'Estimation of a production frontier model: with application to the Zone of Eastern Australia', Australian Journal of Agricultural Economics, Vol.21, No.3 (pp.169-79).

Blalock, H.M. (1972). Social Statistics, McGraw Hill, New York.

Brown, D.D. (1971). Agricultural Development in India's Districts, Harvard University Press, Cambridge.

Byres, T. (1972). 'Dialectics of green revolution', South Asia Review, Vol.5, No.2 (pp.99-116).

Byron, R.P. (1970). 'The restricted Aitken estimation of sets of demand relations', Econometrica, Vol. 38, No. 6 (pp. 816-30).

Carlson, S. (1956). A study in the pure theory of production, Kelley and Millman Inc., New York.

Chandler, R.F. (1973). 'The scientific basis for the increased yield capacity of rice and wheat', in T.K. Poleman and D.K. Fairbairn (eds). Food, Population and Employment, Praeger publications, New York.

Chaudhri, D.P. (1974). 'Effect of farmer's education on agricultural productivity and employment: a case study of Punjab and Haryana states of India (1960-72)', Faculty of Economic Studies, University of New England, Armidale. (mimeo).

Chinnappa, B.N. (1974). 'A note on the accuracy of data collected in the survey', paper presented in the Seminar on Project on Agrarian change in rice growing areas of Tamil Nadu and Sri Lanka, St. John's College, Cambridge, 9-16 December.

Cramer, J.S. (1969). Empirical Econometrics, North Holland Publishing Company, London.

Crawcour, E.S. (1969). 'Japan, 1868-1920', in R.T. Shand (ed.), Agricultural Development in Asia, ANU Press, Canberra.

Crawford, J.G. (1969). 'India', in R.T. Shand (ed.), Agricultural Development in Asia, ANU Press, Canberra.

Crawford, J.G. (1979). 'Research in agricultural policy', a lecture delivered to the Golden Jubilee of the Indian Council of Agricultural Research, New Delhi on 3rd September, 1979.

Dandekar, V.M. (1970). 'Agricultural growth with social justice in overpopulated countries', Economic and Political Weekly, Vol.V, Nos. 29, 30 & 31, (pp.1231-8).

Dantwala, M.L. (1973). 'From Stagnation to Growth: Relative Rules of Technology, Economic Policy and Agrarian Institutions', in R.T. Shand (ed.), Technical Change in Asian Agriculture, Australian National University Press, Canberra.

Dantwala, M.L. (1978). 'Future of institutional reform and technological change in Indian agricultural development', Economic and Political Weekly, Vol.12, Nos. 31, 32 & 33, (pp.1299-1306).

Das Gupta, B. (1977). Agrarian Change and the New Technology in India, UNRISD, Geneva.

Department of Agriculture (1976). Karutharanku Malar, Office of the Deputy Director of Agriculture, Coimbatore.

Desai, B.M. (1973). 'Economics of resource use on sample farms of central Gujarat', Indian Journal of Agricultural Economics, Vol.28, No.1, (pp.71-85).

Desai, D.K. (1972). 'Intensive Agricultural District Programmes Analysis of Results', in P. Chaudhri (ed.), Readings in Agricultural Development, Allen and Unwin, London.

Directorate of Economics and Statistics (1962,1972). Bulletin on Food Statistics, Ministry of Agriculture and Irrigation, Government of India Press, New Delhi.

Etherington, D.M. (1973). An Econometric Analysis of Small Holder Tea Productions in Kenya, East Africa Literature Bureau, Nairobi.

FAO (1975). Introduction and Effects of High-Yielding Varieties of Cereals in India, FAO publications, Rome.

Farrell, M.J. (1957). 'The measurement of productive efficiency', Journal of Royal Statistical Society, Series A (General), Vol.120, Part 3, (pp.253-381).

Frankel, F.R. (1969). 'India's New Strategy of Agricultural Development', Journal of Asian Studies, Vol.28, No.4, (pp.693-710).

Fuss, M. and D.L. McFadden (eds) (1978). Production Economics: A Dual Approach to Theory and Applications, Vol.2, North Holland Publishing Company, Amsterdam.

Gastwirth, J.L. (1972). 'The estimation of the Lorenz Curve and Gini index', Review of Economics and Statistics, Vol.54, No.3, (pp.306-16)

Gini, C. (1962). 'Statistical methods with special reference to agriculture', Metron, Vol.XXII, Nos. 1-2, (pp.169-75).

Government of India (1970). Fourth Five Year Plan 1969-74, Planning Commission, Government of India Press, New Delhi.

Government of India (1974). Draft Fifth Five Year Plan 1974-79, Vol.II, Planning Commission, Government of India Press, New Delhi.

Government of Tamil Nadu (1974). Soil Survey of Gobichettipalayam, Report No.17, Soil Survey and Land Use Organisation, Coimbatore.

Griliches, Z. (1964). 'Research expenditures, education and the aggregate agricultural production function', American Economic Review, Vol.54 (pp.961-74).

Gujarati, D. (1970). 'Use of dummy variables in testing for equality between sets of coefficients in linear regression: a generalisation', The American Statistician, Vol.24, No.5, (pp.18-22).

Halter, A.N. et al. (1957). 'A note on the transcendental production function', Journal of Farm Economics, Vol.39, No.4 (pp.966-74).

Hayami, Y. and V.W. Ruttan (1971). Agricultural Development: An International Perspective, The John Hopkins Press, London.

Hayami, Y. et al. (1976). 'Agricultural Growth Against Land Resource Constraint: The Philippine Experience', Agricultural Economics Department, Paper No.75-14, IRRI, Los Banos, Philippines.

Heady, E.O. and J.L. Dillon (1961). Agricultural Production Functions, Iowa State University Press, Ames, Iowa.

Hoch, I. (1962). 'Estimation of production function parameters combining time-series and cross-section data', Econometrica, Vol.30, No.1, (pp.34-63).

Hsieh, S.C. and V.W. Ruttan (1967). 'Environmental, technological and institutional factors in the growth of rice production: Philippines, Thailand and Taiwan', Food Research Institute Studies, Vol.7, No.3, (pp.307-41).

IBRD (1974). Economic situation and prospects of India, Vol.III.

International Rice Research Institute (1975). Constraints to increasing rice production, International Rice Agro-Economic Network (IREAN) General Report, Los Banos, Philippines.

Johnson, G.L. (1956). 'Problems in studying resource productivity and size of business arising from managerial processes', in E.O. Heady et al. (eds), Resource Productivity, Returns to Scale and Farm Size, The Iowa State College Press, Ames, Iowa.

Johnson, G.L. (1967). 'A note on non-conventional inputs and conventional productivity functions', in C. Eicher and L. Witt (eds), Agriculture in Economic Development, McGraw-Hill, New York.

Johnston, B.F. (1966). 'Agriculture and Economic Development: the Relevence of Japanese Experience', Food Research Institute Studies, Vol.VI, No.3 (pp.251-312).

Johnston, J. (1972). Econometric Methods, McGraw-Hill Kogakusha Ltd., Tokyo.

Johl, S.S. (1973). Gains of green revolution : how they have been shared in Punjab, Department of Economics and Sociology, Punjab Agricultural University, Ludhiana.

Joshi, P.C. (1968). 'Community Development Programme: A Reappraisal', in A.M. Kushro (ed), Readings in Agricultural Development, Allied Publishers, Bombay.

Kale, B.K. (1962). 'On the solution of the likelihood equations by iteration process: the multiparameter case', Biometrica, Vol.49 (pp.479-86).

Klein, L.R. (1962). An Introduction to Econometrics, Prentice-Hall Inc., Englewood, Cliffs.

Kuznets, S. (1969). Economic Growth and Structure, Oxford and IBH Publishing Co., New Delhi.

Ladejinsky, W. (1969). 'The Green Revolution in Punjab: A Field Trip', Economic and Political Weekly, Vol.IV, No.26, (pp.A73-82).

Lau, L.J. (1972). 'Profit functions of technologies with multiple inputs and outputs', Review of Economics and Statistics, Vol.54, No.3 (pp.281-9).

Lau, L.J. and P.A. Yotopoulos (1972). 'Profit, Supply and Factor Demand Functions', American Journal of Agricultural Economics, Vol.54, No.1, (pp.11-18).

Lewis, J.P. (1970). 'Wanted in India: a relevant radicalism', Economic and Political Weekly, Vol.V, Nos. 29, 30 & 31, (pp.1211-26).

Lockwood, B., Mukherjee, P.K. and R.T. Shand (1971). The High Yielding Varieties Programme in India, Part I, PEO and ANU, Department of Economics, Rs. Pac. S., the Australian National University, Canberra.

Marschak, J. and W.J. Andrews (1944). 'Random simultaneous equations and the theory of production', Econometrica, Vol.12 (pp.143-205).

Massell, B.F. (1967). 'Elimination of management bias from production functions fitted to cross-section data: a model and an application to African agriculture', Econometrica, Vol.35, Nos. 3&4, (pp.495-508)

Massell, B.F. (1967). 'Farm management in peasant agriculture: an empirical study', Food Research Institute Studies, Vol.VII, No.2, (pp.205-15).

McFadden, D.L. (1970). 'Cost, revenue and profit functions', Department of Economics, University of California, Berkeley. (mimeo).

Meeuson, W. and J.V.D. Broeck (1977). 'Efficiency estimation from Cobb-Douglas production functions with composed error', International Economic Review, Vol.18, No.2, (pp.435-44).

Mellor, J.W. (1967). 'Towards a Theory of Agricultural Development', in H.M. Southworth and B.F. Johnston (eds), Agricultural Development and Economic Growth, Cornell University Press, Ithaca, New York.

Mellor, J.W. (1976). The New Economics of Growth: A Strategy for India and the Developing World, Cornell University Press, Ithaca, New York.

Mellor, J.W. et al. (1968). Developing Rural India: Plan and Practice, Cornell University Press, Ithaca, New York.

Minhas, B.S. and T.N. Srinivasan (1967). 'New Agricultural Production Strategy Analysed', Yojana, Vol.X, No.1 (pp.20-24).

Mujumdar, N.A. (1970). 'Intra-sectoral Dualism and Agricultural Growth', Economic and Political Weekly, Vol.V, No.26, (pp.A2-A5).

Muller, J. (1972). 'The impact of information on technical efficiency', Stanford University Ph.D. Thesis, Xerox.

Mundlak, Y. (1961). 'Empirical production function free of management bias', Journal of Farm Economics, Vol.XLIII, No.1, (pp.44-56).

Narain, D. (1977). 'Growth of Productivity in Indian Agriculture', Indian Journal of Agricultural Economics, Vol.32, No.1, (pp.1-31).

Nicholls, W.H. (1964). 'The Place of Agriculture in Economic Development', in C. Eicher and L. Witt (eds.), Agriculture in Economic Development, McGraw-Hill, New York.

Ohkawa, K. and H. Rosovsky (1960). 'The Role of Agriculture in Modern Japanese Economic Development', Economic Development and Cultural Change, Vol.IX, No.2 (pp.43-68).

Ott, A.E. (1962). 'Production functions, technical progress and economic growth', International Economic Papers, No.11, (pp.102-40).

PEO-ANU (1977). The High Yielding Varieties Programme in India 1970-75, Part II, Government of India Press, New Delhi.

Raj, K.N. (1969). 'Some questions concerning growth, transformation and planning of agriculture in developing countries', Journal of Development Planning, Vol.I, No.1 (pp.15-38).

Rao, C.H.H. (1975). Technological Change and the Distribution of Gains in Indian Agriculture, MacMillan, New Delhi.

Rao, V.K.R.V. (1966). Agricultural Development in the Fourth Plan, Planning Commission, Government of India.

Roumasset, J.A. (1975). Rice and Risk, North-Holland Publishing Co., Amsterdam.

Schultz, T.W. (1964). Transforming Traditional Agriculture, Yale University Press, New Haven.

Schultz, T.W. (1968). Economic Growth and Agriculture, McGraw-Hill Book Company, New York.

Sen, B. (1974). The Green Revolution in India: A Perspective, Wiley Eastern Private Limited, New Delhi.

Sen, S. (1974). A Richer Harvest, Tata - McGraw-Hill, New Delhi.

Shand, R.T. (1969). 'Perspectives on Asia' in R.T. Shand (ed.), Agricultural Development in Asia, Australian National University Press, Canberra.

Shand, R.T. (1976). 'The Green Revolution in India - a Decade and After', unpublished paper presented at a work-in-progress seminar, Department of Economics, Rs. Pac. S., Australian National University Canberra.

Sidhu, S.S. (1974). 'Economics of Techical Change in Wheat Production in the Indian Punjab', American Journal of Agricultural Economics, Vol.56, No.2, (pp.217-226).

Shand, R.T. (1978). 'Recent Indian Experience of the International Transfer of Cereal Grains Technology', Development Studies Centre, The Australian National University, (mimeo).

Sidhu, S.S. (1972). 'Economics of technical change in wheat production in Punjab, India', unpublished doctoral dissertation, University of Minnesota.

Subramanian, A. (1970). 'Agro-climatic regions of Tamil Nadu and regional research stations', Tamil Nadu Agricultural University, Coimbatore, (mimeo).

Subramanian, A. et al. (1971). 'Performance of new high yielding varieties of rice at Coimbatore', The Madras Agricultural Journal, Vol.58, No.7, (pp.649-58).

Subramaniam, C. (1979). The New Agricultural Strategy: The First Decade and After, Vikas Publications, New Delhi.

Swaminathan, M.S. (1969). 'Scientific Implications of HYVP Programme', Economic and Political Weekly, Vol.IV, Nos. 1&2, (pp.67-75).

Theil, H. (1963). 'On the use of incomplete prior information in regression analysis', Journal of American Statistical Association, Vol.58, (pp.401-14).

Theil, H. (1967). Economics and information theory, North-Holland Publishing Company, Amsterdam.

Theil, H. (1971). Principles of Econometrics, John Wiley & Sons, Inc., New York.

Timmer, C.P. (1970). 'On measuring technical efficiency', Food Research Institute Studies, Vol.IX, No.2, (pp.99-171).

Timmer, C.P. (1971). 'Using a probabilistic frontier production function to measure technical efficiency', Journal of Political Economy, Vol.79, No.4 (pp.776-94).

Vyas, V.S. (1975). India's High Yielding Varieties Programme in Wheat, 1966-67 to 1971-72, Centro Internacional de Mejoramiento de Maiz Y Trigo, Mexico.

Wald, A. (1943). 'Tests of statistical hypotheses concerning several parameters when the number of observations is large', Transaction of the American Mathematical Society, Vol.45, (pp.426-82).

Walters, A.A. (1963). 'Production and Cost Functions', Econometrica, Vol.31, Nos.1-2, (pp.1-66).

Walters, A.A. (1968). An Introduction to Econometrics, MacMillan, London.

Yotopoulos, P.A. (1974). 'Rationality, efficiency and organisational behaviour through the production function, darkly', Food Research Institute Studies, Vol.13, No.3 (pp.263-74).

Yotopoulos, P.A. and J.B. Nugent (1976). Economics of Development: Empirical Investigations, Harper & Row, New York.

Yotopoulos, P.A. et al. (1970). 'Labour intensity and relative efficiency in Indian Agriculture', Food Research Institute Studies, Vol.9, (pp.43-45).

Yotopoulos, P.A. and L.J. Lau (1973). 'A test for relative economic efficiency: some further results', American Economic Review, Vol.63, No.1 (pp.214-23).

Zellner, A. (1962). 'An efficient method for estimating seemingly unrelated regression equations and tests for aggregation bias', Journal of American Statistical Association, Vol.57 (pp.348-68).